

ENTRAINMENT OF PHYTOPLANKTON AT THE  
DONALD C. COOK NUCLEAR PLANT - 1977

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The Donald C. Cook Nuclear Plant is a 2200 megawatt steam electric generating station situated on the southeastern shore of Lake Michigan about 18 km south of St. Joseph, Michigan. At full operation, the plant will use roughly 6300 m<sup>3</sup>/min of lake water in once-through cooling of its condensers. Waste heat is returned to the lake in cooling water heated to a maximum of 12-13C° above intake temperature for unit #1 and 9-10C° above lake temperature for unit #2 as stated in the Environmental Technical Specifications for the plant. The plant uses chlorination twice daily for chemical defouling of heat exchangers and turbine condensers. At the time of sampling, only unit #1 of the plant was operating. It uses roughly 2700 m<sup>3</sup>/min of lake water for once-through cooling.

The Environmental Technical Specifications of the plant require an assessment of phytoplankton abundance, viability, and species composition to be made on a monthly basis on samples collected in the early morning, at mid-day, and in the late evening.

## INTRODUCTION

### SUMMARY AND APPLICATION TO THE DONALD C. COOK NUCLEAR PLANT

Past studies described in the literature are summarized in Rossmann et al. (1977). These have shown that phytoplankton may suffer inhibition or death due to entrainment and condenser passage. In addition, changes in community structure have been noted. Various authors have concluded that temperature rises which can be tolerated range from 8C° to 11C°. The actual delta-T permissible is related to the intake water temperature. The lower the intake water temperature the greater the tolerable temperature rise. If chlorination

is also taking place, the phytoplankton may be killed outright or suffer varying degrees of inhibition. At elevated temperatures, communities have been observed to exhibit a decreased diversity promoted by a shift from a diatom dominated community to one dominated by either green algae or blue-green algae in heated waters.

Finally, some evidence exists which suggests that the phytoplankton may be mildly stimulated by mechanical pumping (Gurtz and Weiss 1972).

#### PREVIOUS STUDIES AT THE COOK PLANT

In response to the above possible alterations of the phytoplankton community in the vicinity of the plant, two major studies have been initiated. The first study began in 1968. It is directed at determining the long-term effect of the plant on the phytoplankton. This study includes the counting and identification of phytoplankton species at both plant-influenced and non-influenced stations. These data have been used to establish pre-operational phytoplankton trends and variations in the lake against which operational data can be compared. The results of these studies have been reported by Ayers et al. (1970), Ayers et al. (1971), Ayers et al. (1972), Ayers and Seibel (1973), Ayers et al. (1974), Ayers and Kopczynska (1974), Ayers (1975a), Ayers (1975b), Ayers et al. (1977), Ayers (1978), and Ayers and Wiley (1979).

The second study is being used to ascertain the immediate effect of the plant on the entrained phytoplankton. It will also be used to monitor long-term changes in the phytoplankton. Results of this continuing study for the year 1977 are presented here. The monitoring results for 1975 and 1976 are found in Rossmann et al. (1977) and Rossmann et al. (1979) respectively.



## SAMPLE HANDLING AND ANALYSIS

Studies pertaining to entrained phytoplankton at the Donald C. Cook Nuclear Power Plant unit #1 began in February 1975 and continue at present. Investigation of plant impact on phytoplankton viability, abundance, and species composition has been made in accordance with the Environmental Technical Specifications for the plant. Sampling was conducted on a monthly basis with three approximately one-half hour sampling periods in a 24-hour span: after evening twilight, before morning twilight, and at noon, respectively. During each sampling period, fourteen samples were collected, seven from the intake forebay and seven from the discharge forebay (Figure 1). Of each seven, two samples were preserved for microscopic investigation of abundance and species composition, and the remaining five were used for spectrophotometric determination of chlorophylls a, b, and c and phaeophytin a with subsequent calculation for the phaeophytin a/chlorophyll a ratio as an indicator of phytoplankton viability. During the first sampling period, five additional samples were collected from both the intake and discharge forebays. The ten samples were incubated at the intake temperature for approximately 36 hours and treated in the same manner as non-incubated samples for analysis of the chlorophylls and phaeophytin a.

Throughout 1977, samples were collected at intake grate MTR 1-5 from a depth of 5.5 m. A study of horizontal and vertical phytoplankton concentrations in the intake forebay has confirmed our choice of MTR 1-5 at a depth of 5.5 m to be a representative sampling point (Rossmann et al. 1977).

Water was collected by diaphragm pumps from the intake and discharge forebays through 7.7-cm diameter hoses at a rate of roughly 227 L/min. As the water was pumped, the intake and discharge water temperatures were measured,

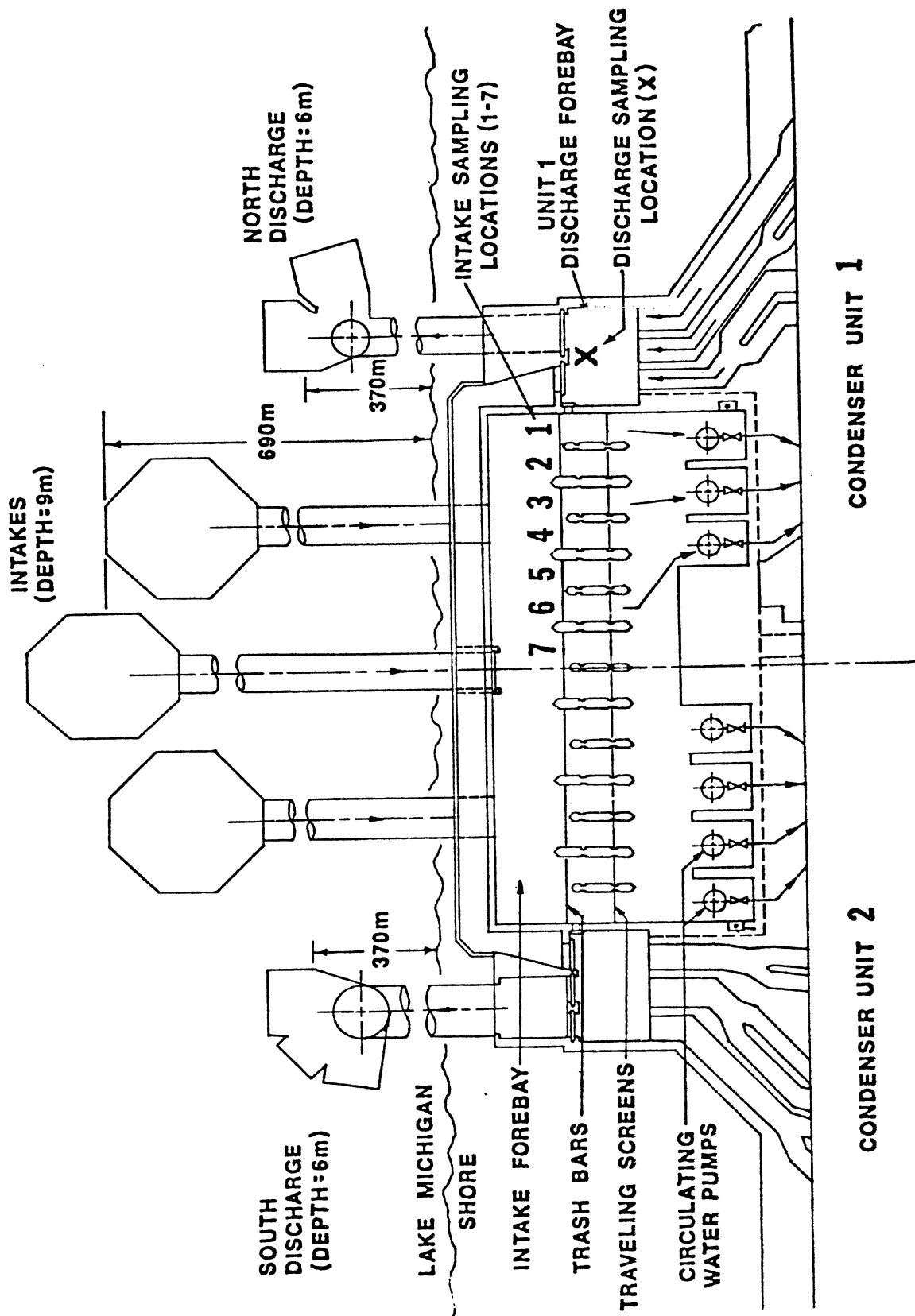


FIG. 1. Sampling locations in the Donald C. Cook Nuclear Plant screenhouse.

and samples were collected in one-liter polyethylene bottles. Since unit #1 uses  $2.7 \times 10^6$  L/min for cooling, the samples collected during a one-half hour sampling time represent approximately  $6.2 \times 10^{-6}\%$  of the water passing through the plant for the chlorophylls and  $2.5 \times 10^{-6}\%$  of the water passing through the plant for the microscopic phytoplankton analysis.

#### PHYTOPLANKTON

Phytoplankton samples were collected from both the intake and discharge forebays (Figure 1). They were, for the most part, collected in duplicate in twice-rinsed, one-liter brown polyethylene bottles and fixed with 6 mL of Lugols' iodine-potassium iodide-glacial acetic acid solution. Slide preparation was similar to the settle-freeze method of Sanford et al. (1969). One-liter samples were settled in graduated cylinders for 2 days, after which time 900 mL of supernatant were siphoned off. The remaining 100 mL were then agitated to resuspend the settled matter, and 18 mL were poured into a cylindrical plexiglass settling chamber with a microscope slide at its base. Various dilutions were used to facilitate enumeration and identification when there were high concentrations of suspended material. The chambers were secured to the slides with a minimal amount of stopcock grease on their ends and the cylinder-slide combinations were held by clamps onto a quarter inch thick aluminum plate. Freezing of the bottom 1.5 mL was accomplished by placing the entire apparatus on a block of dry ice for approximately 85 seconds. The supernatant was poured off when the ice at the bottom of the chamber had melted sufficiently, the chamber was removed from the slide, and the slide with its thin wafer of ice and water was dehydrated in an anhydrous alcohol chamber for 2 days. This was followed by 2 days in a toluene chamber

to prepare the sample for permanent mounting under a cover slip in Permount.

All counting was done on a Leitz Ortholux microscope at 1250X with a stage micrometer calibrated field width of 90  $\mu\text{m}$ . Identification of specimens was carried to species and variety when possible. Enumeration was all in cells per milliliter except for blue-green filaments with cylindrical trichomes which were in filaments per milliliter. Two complete transects were made on each slide, one horizontal and one vertical, to help offset any patchiness that could occur in distribution. A minimum of 500 cells was counted for each slide to ensure reasonable group percentages, more transects and/or higher counts being necessary if a fairly large number or proportion of the cells were in colonial formations.

#### CHLOROPHYLLS AND PHAEOPHYTIN a

Each water sample was passed through a 4.25 cm diameter Whatman GF/C glass fiber filter positioned with plastic-tipped forceps in a 250 mL Millipore filtering apparatus. After most of the water had passed into the filtering flask, 1 mL of saturated  $\text{MgCO}_3$  was added (1 g  $\text{MgCO}_3 \cdot 4\text{H}_2\text{O}$ /100 mL distilled water). The filters were rolled up with the forceps, placed in amber vials, frozen, and transported back to the laboratory. The samples selected for incubation were not filtered but immediately placed in an incubator with the bottle caps removed and allowed to incubate for 24 to 48 hours at the intake temperature. Following this they were filtered and treated in the same manner as the non-incubated samples, a modification of the method described by Strickland and Parsons (1972).

In the laboratory, the frozen samples were prepared by grinding with a tissue grinder and extracting into 90% acetone. The 90% acetone was prepared

by swirling reagent grade acetone with anhydrous  $\text{Na}_2\text{CO}_3$  and passing it through a Whatman #4 filter, containing some additional  $\text{Na}_2\text{CO}_3$ , into a volumetric flask having the appropriate volume of distilled water for a 90% solution (v/v). Sample vials were removed from the freezer in groups of five and placed on ice in a dark ice chest next to the grinding apparatus. Sample vials were removed singly from the ice chest, and the frozen filters were transferred with forceps to a tissue grinding tube immersed in an icebath. The filter was ground at approximately 100 rpm for 4 minutes in 1.5 - 2 mL of 90% acetone in a tissue grinding tube; the grinding tube was held firmly against the rotating pestle, lowered briefly, and raised back against the pestle approximately every 15 seconds. If the filter and 90% acetone were not reduced to a homogenous slurry after 4 minutes, grinding was continued until this was accomplished, generally within 1 minute more. The contents of the grinding tube were then poured into a 12 mL screw cap centrifuge tube. The tissue grinder was rinsed three times with 90% acetone into the centrifuge tube to adjust the final volume of 90% acetone used to 10 mL. The centrifuge tube was then capped and placed in the ice chest. After all five samples were ground, they were placed in a dark refrigerator and extracted for 24 - 36 hours. Following extraction, each sample was inverted three times and centrifuged with the tube in an ice bath for 4 minutes at 2,000 rpm to separate the filter fibers and  $\text{MgCO}_3$  from the extract. The centrifuged samples were then refrigerated until shortly before analysis.

For analysis, individual samples were warmed to room temperature in a light tight container. The extract was transferred by a pasteur pipette to two 5-cm-path long cuvettes. Two drops of 50% v/v HCl were added to the sample in one cuvette, which was shaken and then held for 4 minutes. The other cuvette was placed in a Beckman model 25 spectrophotometer where sample absorbances

were measured over a scan from 600 to 750 nm. The absorbance of the acidified sample was then measured over the same range.

## CONDITIONS AT TIME OF COLLECTION

### TEMPERATURE AND PHYSICAL EVENTS

Table 1 contains a summary of intake and discharge temperatures for those periods of time when phytoplankton entrainment samples were collected. During October 1977, phytoplankton collection coincided with large rapid temperature changes due to upwelling of colder bottom water along the eastern shore of Lake Michigan in the vicinity of the D. C. Cook Nuclear Plant. Similar events took place in the weeks preceding the June 1977, July 1977, September 1977, and October 1977 entrainment collections. Upwelling transports colder bottom water, rich in nutrients and containing its own phytoplankton assemblage, to nearshore regions of the lake. Any mixing of these hypolimnetic and epilimnetic waters yields a water mass having characteristics of each and results in an increased sample variability. The increased heterogeneity is particularly important if upwelling occurs during sampling periods.

### CHLORINATION

Chlorination occurs twice daily at the Cook Plant. In each case, the period of chlorination is one-half hour. Table 2 is a compilation of the chlorination times for those days the plant was operating in 1977. Only on September 12 at 2036 and 2055 EST did our sampling coincide with a period of chlorination.

TABLE 1. Intake and discharge entrainment temperatures at the time of sampling during 1977.

<u>Date</u>	<u>Time</u>	<u>Intake, °C</u>	<u>Discharge, °C</u>
March 7, 1977	Evening Twilight	0.9	11.0
8	Morning Twilight	0.8	11.0
8	Noon	0.8	11.6
April 11, 1977	Evening Twilight	7.9	17.5
12	Morning Twilight	7.2	17.1
12	Noon	7.5	17.6
May 16, 1977	Evening Twilight	14.5	22.2
17	Morning Twilight	14.0	21.9
17	Noon	13.9	22.0
June 13, 1977	Evening Twilight	15.0	23.0
14	Morning Twilight	14.1	22.7
14	Noon	15.1	22.7
July 11, 1977	Evening Twilight	19.0	26.2
12	Morning Twilight	19.1	26.5
12	Noon	20.3	27.5
August 8, 1977	Evening Twilight	21.2	32.4
9	Morning Twilight	21.5	32.0
9	Noon	21.8	33.3
September 12, 1977	Evening Twilight	19.0	28.5
13	Morning Twilight	18.3	28.0
13	Noon	18.7	28.1
October 10, 1977	Evening Twilight	13.7	22.4
11	Morning Twilight	13.5	22.0
11	Noon	21.2	25.0
November 7, 1977	Evening Twilight	10.9	17.8
8	Morning Twilight	11.2	20.3
8	Noon	11.3	18.4
December 13, 1977	Evening Twilight	----	----
14	Morning Twilight	----	----
14	Noon	----	----

TABLE 2. Chlorination times on the days of phytoplankton entrainment studies during 1977.

Date	Time, EST
March 7	--
8	--
April 11	--
12	0900 - 0935, 2100 - 2135
May 16	0800 - 0840
17	0800 - 0840
June 11	--
12	--
July 11	0800 - 0830
12	0800 - 0835
August 8	0800 - 0835
9	0800 - 0835, 2000, - 2035
September 12	0800 - 0835, 2000 - 2030
13	0805 - 0830, 2000 - 2035
October 10	--
11	--
November 7	--
8	--
December 13	0900 - 0935, 2100 - 2135
14	0900 - 0930, 2100 - 2130



## RESULTS AND DISCUSSION

### NUTRIENTS

#### Quality Control

During 1977, samples for nutrient analyses were collected in triplicate from the intake forebay of the plant at location MTR 1-5. Collection coincided with the noon sampling period for phytoplankton. Each sample was analyzed for orthophosphate, nitrate, nitrite, and dissolved silica. The methodology used is described in Rossmann et al. (1979). To ensure the accuracy of our results, standard United States Environmental Protection Agency reference samples were analyzed. A comparison of our results with the known concentrations are contained in Table 3. Unfortunately we were not able to obtain such reference standards for dissolved silica. However, a standard was prepared from pure quartz ( $\text{SiO}_2$ ) by fusion with lithium metaborate (Medlin et al. 1969). The results are contained in Table 3.

TABLE 3. Comparison of nutrient results with the known concentration for United States Environmental Protection Agency reference nutrient samples.

Nutrient	GLRD Value <sup>1</sup>	Prepared Standard <sup>2</sup>	EPA Value
$\text{PO}_4\text{-P}$ , ppb	20.8 (0.208)		21.0
$\text{NO}_3\text{-N}$ , ppm	1.12 (0.00587)		1.11
$\text{NO}_3\text{-N}$ , ppm	0.219 (0.000151)		0.20
$\text{SiO}_2$ , ppm	1.86 (0.00)	2.00	

<sup>1</sup> The mean is followed by the standard error in parentheses.

<sup>2</sup> Prepared from quartz ( $\text{SiO}_2$ ) as a quality control.

Part of the reason for preparing a dissolved silica standard was a bad certified standard received from an outside supplier which required correction of most dissolved silica results for 1977.

#### Entrained Lake Water Concentrations

Concentrations of each of the nutrients varied throughout the year in response to upwelling, storm events, and utilization by the phytoplankton (Table 4). Nitrite was only detectable during isothermal conditions or periods of upwelling. At other times, the intakes for the plant sample only epilimnetic water where nitrite is completely oxidized to nitrate. During October 1977, sample collection coincided with large temperature changes due to upwelling of colder bottom water along the eastern shore of Lake Michigan in the vicinity of the D. C. Cook Nuclear Plant. Similar events took place in the weeks preceeding the June 1977, July 1977, September 1977, and October 1977 sample collections. These events kept orthophosphate concentration above 0.9 ppb. Only during August did the orthophosphate drop to 0.7 ppb. This pattern was not evident for nitrate, which seemed to have no pattern. Dissolved silica was high in March. It began to decrease in April with commencement of the spring diatom bloom. Concentration remained low until the October upwelling which provided dissolved silica-rich waters to this nearshore region of the lake. Dissolved silica concentrations decreased through December, perhaps signalling commencement of the winter diatom bloom.

TABLE 4. Monthly variation of nutrients during 1977.<sup>1</sup>

Month	ppb Orthophosphate (P)	ppm Nitrate (N)	ppm Nitrite (N)	ppm Dissolved Silica (SiO <sub>2</sub> )
March	1.35(.134)	1.87(.122)	0.00204(.00204)	0.905(0.000)
April	1.35(.165)	0.966(.251)	0.00341(.000791)	0.657(.0655)
May	1.26(.104)	1.09(.0698)	0.0(0.0)	0.127(.0268)
June	1.24(.167)	0.839(.0506)	0.00380(.0038)	0.210(.0568)
July	0.915(.0546)	2.35(.484)	0.0(0.0)	0.156(.129)
August	0.742(.193)	0.715(.0100)	0.0(0.0)	0.416(.0395)
September	2.18(.720)	0.712(.0278)	0.0(0.0)	0.476(.110)
October	1.45(.173)	1.16(.0418)	0.0146(.00730)	1.13(.0433)
November	0.975(.0547)	0.996(.104)	0.0312(0.0126)	0.682(.108)
December	1.02(.0257)	0.653(.0276)	0.0307(.000456)	0.396(.0313)

<sup>1</sup>Means are followed by standard errors in parentheses.

## PHYTOPLANKTON

### Monthly Variations of Major Phytoplankton Groups Entrained

The major groups of phytoplankton under consideration are coccoid blue-green, filamentous blue-green, coccoid green, filamentous green, flagellates, centric diatoms, pennate diatoms, desmids, and other algae. With the exception of the desmids, whose population level is relatively low throughout the year, and whose contribution to the total annual algal abundance is of no significance, all major groups represent significant contributions to the composition of the total algal assemblage. The succession of diatoms, blue-green algae, green algae, and flagellates is of importance in this system (Rossmann et al. 1979). These successions go through a predictable pattern throughout the calendar year.

Diatoms contribute the largest share to the total annual algal population and include two major groups: centric and pennate diatoms. These groups have a close ecological affinity. In general, diatoms are relatively abundant in spring; they reach their peak in April and decrease thereafter. This decrease in abundance after April is due to thermal stratification and a rise in ambient temperature. Thermal stratification and an increase in diatoms lead to nutrient depletion, particularly depletion of dissolved silica which is an essential ingredient for the growth of diatoms. The low population density continues until October when a decrease of water temperature and physical mixing processes create an isothermal water column. During the establishment of an isothermal water column, major nutrients such as dissolved silica are replenished, leading to a relatively high density of diatoms throughout the winter months.

The green algae population including coccoid green and filamentous green algae, is generally low from January through May or June. It reaches a peak density during the warm water months of May through September, and then declines during October through December.

Blue-green algae are low in concentration during January through April or July. Population abundance is highest during June through October when water temperatures are relatively high, and its abundance decreases in November and December with decreased water temperature.

Flagellates are relatively low in concentration during January through March. A population peak generally occurs in April or May, and a large population often continues through December.

The patterns of succession described above serve as a general temporal distribution of species occurring in Lake Michigan, but they are seldom found to be completely coincident with the species found in the nearshore region of Lake Michigan where factors dominating the system vary greatly from year to year in degree or in time of occurrence. Furthermore, in the case of the entrainment samples, thermal effluents from the power generating plant offer an additional variable which may cause further deviation or may offset the described patterns of succession. Since the general pattern of succession does not fully describe yearly microvariations, it would be of benefit to look at the observed patterns of 1977 algal succession.

Coccoid blue-green algae had a low population density in March, April, May, June, and July which increased rapidly in August and then remained high throughout the rest of the year (Table 5). Comparisons between the total abundance of the coccoid blue-green in 1977 with those in 1976 and 1975 indicate that no significant change was observed between 1975 and 1977, but the 1977 abundance was double that of 1976.

TABLE 5. Monthly variation of coccoid blue-green algae during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	461.(149)		
February	109.(59.7)	254.(71.7)	
March	257.(186.)	347.(110.)	137.(57.2)
April	312.(125.)	143.(63.6)	110.(76.2)
May	689.(169.)	87.1(46.6)	47.3(27.3)
June	235.(155.)	33.6(25.1)	114.(45.6)
July	1050.(155>)	57.8(26.5)	133.(28.5)
August	286.(53.2)	439.(93.8)	1210.(254.)
September	1220.(169.)	339.(118.)	917.(93.6)
October	945.(212.)	560.(196.)	727.(145.)
November	600.(166.)	422.(121.)	1320.(289.)
December	176.(106.)	275.(73.4)	872.(124.)
Yearly Mean	535.(117.)	285.(50.1)	559.(159.)

' Mean is followed by the standard error.

Filamentous blue-green algae were less numerous than coccoid blue-green algae (Table 6). Occurring in April, the maximum count was 110 cells/mL. The comparison between abundances of 1977 and those of 1975 and 1976 showed the 1977 population to decrease to one-half those of 1975 and 1976.

Coccoid green algae abundances were low throughout the first part of the year until the month of June (Table 7). A relatively high population occurred in the months of July, August, and October, with the population densities less than 66 cells/mL in the months of September, November, and December. A significant reduction in mean population density was seen between 1977 and the years 1976 and 1975.

Filamentous green algae were less numerous than coccoid green algae, and showed a population density above 15 cells/mL in only April, July, and November (Table 8). A slight reduction in population mean was encountered between 1976 and 1977 but not between 1975 and 1977.

Flagellates were numerous, and contributed an important share to the total annual algal population (Table 9). They had a relatively high density in March, April, and May, reached their peak in May, and maintained a relatively low density thereafter until October, when the population reached another high. The flagellates continued this high level through November, then decreased markedly in December. No significant change in mean annual abundance between 1977 and 1975 or 1976 was observed.

Centric diatoms were relatively abundant in spring, reached a population peak in April, and decreased sharply in May (Table 10). The maximum population found in July was coincident with the time of upwelling, which often leads to an increase in the major nutrients such as dissolved silica. The population remained relatively low throughout the rest of the year. A two-fold reduction in mean population density was noted for 1977 relative to 1975 and 1976.

TABLE 6. Monthly variation of filamentous blue-green algae during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January		22.0(8.06)	
February	28.2(8.10)	16.4(3.53)	
March	59.7(17.6)	13.4(2.53)	16.7(3.19)
April	27.6(5.40)	57.9(5.16)	110.(76.2)
May	103.(37.0)	457.(52.8)	17.5(4.09)
June	314.(38.1)	81.1(16.1)	24.3(8.29)
July	95.1(25.5)	72.1(12.7)	59.9(14.3)
August	8.90(2.70)	9.24(3.08)	17.6(6.37)
September	17.3(9.20)	46.8(15.8)	25.0(8.84)
October	98.8(34.0)	45.9(23.8)	21.4(7.61)
November	21.6(17.8)	6.35(4.31)	12.7(3.13)
December	15.4(7.70)	74.5(44.3)	45.2(18.6)
Yearly Mean	71.8(26.5)	75.2(35.6)	35.0(9.54)

' Mean is followed by the standard error.



TABLE 7. Monthly variation of coccoid green algae during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	42.2(12.2)		
February	39.3(14.2)	29.5(11.1)	
March	55.2(24.7)	22.9(7.63)	21.1(4.43)
April	49.7(14.8)	57.9(12.3)	51.4(8.31)
May	47.1(19.7)	145.(30.6)	15.3(4.89)
June	141.(23.2)	98.4(26.9)	39.2(15.8)
July	1000.(107.)	689.(123.)	152.(19.2)
August	197.(37.1)	494.(46.8)	115.(16.5)
September	176.(24.2)	755.(129.)	54.4(8.31)
October	116.(16.1)	242.(37.1)	232.(85.4)
November	138.(66.9)	134.(36.1)	65.1(18.2)
December	110.(47.8)	240.(54.5)	49.5(11.4)
Yearly Mean	188.(82.8)	246.(74.6)	79.5(21.5)

' Mean is followed by the standard error.

TABLE 8. Monthly variation of filamentous green algae during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	31.6(17.4)		
February	18.0(9.70)	2.00(1.20)	
March	34.8(12.6)	16.4(6.62)	6.63(4.37)
April	0.0(0.0)	18.1(10.5)	18.2(12.3)
May	1.50(1.50)	57.8(23.0)	4.63(2.32)
June	29.5(20.6)	55.0(14.0)	.417(.417)
July	0.3(0.3)	37.3(11.1)	22.9(4.79)
August	0.8(0.6)	4.28(2.52)	0.0(0.0)
September	0.2(0.2)	13.7(6.13)	1.86(.888)
October	2.8(1.1)	9.67(2.47)	6.63(4.02)
November	1.5(1.2)	6.35(5.48)	26.8(6.92)
December	14.4(7.3)	5.52(2.39)	14.0(6.97)
Yearly Mean	9.44(3.87)	21.5(5.64)	10.2(3.06)

' Mean is followed by the standard error.

TABLE 9. Monthly variation of flagellated algae during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	110.(18.7)		
February	90.8(20.8)	252.(32.1)	
March	272.(56.6)	268.(25.5)	628.(60.2)
April	857.(190.)	351.(36.6)	1010.(116.)
May	641.(82.3)	1350.(220.)	1200.(160.)
June	802.(148.)	633.(70.5)	235.(30.6)
July	561.(94.6)	452.(31.6)	267.(33.9)
August	504.(56.7)	482.(86.8)	376.(31.9)
September	587.(71.6)	426.(70.3)	302.(57.8)
October	696.(85.4)	559.(91.7)	550.(91.8)
November	417.(51.9)	524.(47.6)	754.(156.)
December	368.(59.9)	415.(84.2)	78.9(19.3)
Yearly Mean	527.(69.0)	485.(89.0)	540.(114.)

' Mean is followed by the standard error.

TABLE 10. Monthly variation of centric diatoms during  
1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	1810.(191.)		
February	1040.(130.)	560.(45.0)	
March	1290.(111.)	807.(56.8)	463.(57.7)
April	2550.(427.)	930.(51.1)	779.(83.9)
May	1190.(170.)	1400.(189.)	139.(23.1)
June	817.(64.3)	212.(18.3)	451.(91.5)
July	914.(108.)	3370.(361.)	967.(65.9)
August	102.(23.9)	272.(25.9)	175.(12.0)
September	69.2(8.3)	1060.(157.)	183.(14.8)
October	286.(21.2)	644.(50.9)	140.(18.1)
November	404.(64.5)	1090.(69.4)	194.(24.2)
December	1700.(132.)	503.(58.8)	165.(18.5)
Yearly Mean	945.(224.)	1050.(249.)	366.(93.7)

' Mean is followed by the standard error.

Pennate diatoms contributed the largest share to the total algal biomass in 1977 (Table 11). They were high in density in spring, reached a peak in April, and decreased thereafter. A minor population peak in June may be attributed to an upwelling. The population remained low until October, when thermal stratification ceased. A significant reduction in mean annual density was noted for 1977 relative to 1975 and 1976.

Desmids were consistently low throughout 1977 (Table 12). The maximum population density did not exceed 2 cells/mL; the peak was in May. No significant change in population was found from 1975 to 1977.

The group of "other algae" is composed of phytoplankton which do not belong to any of the groups mentioned above. Such phytoplankton reached peaks of abundance in April, July, August, October, and November. The population maximum was found in August (Table 13). A slight decrease in population size was noted between 1976 and 1977, but no change was observed between 1975 and 1977.

Total phytoplankton abundance reached peaks in April, July, August, October, and November (Table 14). The maximum was in April, corresponding with a maximum of pennate diatoms, which contribute the greatest share of individuals to this population maximum. The second highest population was encountered in November after isothermal conditions resumed. A minor peak in July correlated well with the occurrence of an upwelling. A reduction in population size of about one-third was seen between the 1977 samples and those of 1975 and 1976.

The major changes observed between the year of 1977 and the years of 1975 and 1976 were: (1) marked reduction in abundance of centric diatoms, pennate diatoms, filamentous green algae, coccoid-green algae, filamentous blue-green algae, and total algae; (2) an increase in the abundance of coccoid blue-green

TABLE 11. Monthly variation of pennate diatoms during  
1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January		991.(186.)	
February	1640.(196.)	265.(43.0)	
March	1340.(146.)	329.(46.3)	1210.(90.6)
April	1160.(306.)	1340.(123.)	1710.(187.)
May	3040.(278.)	864.(158.)	383.(45.0)
June	1220.(102.)	332.(29.9)	743.(129.)
July	90.8(12.8)	2900.(459.)	487.(44.8)
August	84.8(16.8)	1250.(207.)	73.2(10.1)
September	270.(52.7)	1920.(411.)	146.(15.5)
October	295.(34.6)	498.(36.6)	822.(45.2)
November	501.(74.2)	824.(100.)	724.(100.)
December	333.(43.4)	1320.(148)	548.(50.2)
Yearly Mean	907.(271.)	1070.(220.)	685.(155.)

' Mean is followed by the standard error.

TABLE 12. Monthly variation of desmids during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	0.0(0.0)		
February	0.8(0.5)	.283(.191)	
March	0.8(0.5)	.417(.298)	.142(.142)
April	1.2(1.2)	.825(.592)	.275(.275)
May	3.0(0.0)	1.65(.642)	1.52(.583)
June	2.5(0.9)	.142(.142)	1.25(.580)
July	2.2(1.2)	1.25(.843)	1.47(.325)
August	0.4(0.2)	.550(.371)	1.11(.587)
September	0.3(0.3)	.275(.275)	.0667(.0667)
October	0.8(0.4)	0.0(0.0)	0.0(0.0)
November	0.5(0.3)	0.0(0.0)	.825(.431)
December	0.0(0.0)	.417(.298)	1.38(.604)
Yearly Mean	1.14(.298)	.484(.150)	.804(.197)

' Mean is followed by the standard error.

TABLE 13. Monthly variation of other algae during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	62.4(18.1)		
February	7.03(3.2)	58.3(30.4)	
March	29.4(4.4)	39.9(5.93)	16.7(5.49)
April	70.0(16.9)	91.1(42.8)	167.(20.8)
May	84.0(17.2)	148.(27.8)	55.6(10.5)
June	148.(29.0)	104.(12.1)	37.9(7.65)
July	480.(57.1)	361.(52.3)	193.(22.0)
August	55.0(22.1)	192.(19.8)	206.(26.7)
September	31.6(6.2)	481.(54.7)	62.0(7.15)
October	44.0(5.0)	166.(23.7)	183.(21.4)
November	65.7(13.0)	84.7(14.5)	119.(15.6)
December	71.0(13.1)	42.0(7.67)	63.4(15.1)
Yearly Mean	98.7(39.7)	153.(39.5)	110.(22.6)

' Mean is followed by the standard error.



TABLE 14. Monthly variation of total algae during 1975, 1976, and 1977 (cells/mL).

<u>Month</u>	<u>1975'</u>	<u>1976'</u>	<u>1977'</u>
January	3530.(429.)		
February	2970.(318.)	1410.(147.)	
March	3340.(421.)	1840.(182.)	2500.(206.)
April	5020.(816.)	2990.(200.)	3890.(336.)
May	5800.(413.)	4520.(396.)	1860.(214.)
June	3710.(302.)	1550.(132.)	1650.(249.)
July	4200.(243.)	7940.(836.)	2280.(156.)
August	1270.(92.8)	3140.(292.)	2170.(296.)
September	2380.(208.)	5050.(675.)	1690.(140.)
October	2490.(286.)	2720.(291.)	2680.(285.)
November	2150.(259.)	3090.(237.)	3210.(428.)
December	2790.(170.)	2870.(312.)	1840.(189.)
Yearly Mean	3280.(399.)	3390.(519.)	2380.(228.)

' Mean is followed by the standard error.

algae between 1976 and 1977, but not between 1975 and 1977.

### Monthly Variations in Phytoplankton Community Structure

#### Occurrences of Dominant and Co-dominant Forms --

Any species constituting 10% or more of the total population in a sample is considered a dominant form. The frequency of these dominant forms occurring in the monthly samples can be used as a measure of the degree of probable occurrence among the dominant species in the system from which the entrainment sample is taken. A comparison of these monthly frequencies between the years in which the plant has been in operation can reveal whether any change has occurred in these species during the period. Since many species, although dominant in some samples, only appeared relatively infrequently, consideration of them would become a tedious task. More importantly, the resulting complexity may obscure the existing patterns. For this reason, we are concentrating only on those species which were dominant in at least 50% of the total monthly samples. The monthly comparisons between the years were made starting in March, when the 1977 counts began.

In March, Tabellaria fenestrata v. intermedia, and centric diatoms were dominant in 1975; Cyclotella stelligera and flagellates were dominant in 1976; and flagellates, Fragillaria crotonensis, and Synedra filiformis were dominant in 1977 (Table 15). During April, the dominant forms were flagellates and Cyclotella stelligera in 1975; Fragilaria crotonensis and Asterionella formosa in 1976; and flagellates, Fragilaria crotonensis, chrysophycean flagellates, and Synedra filiformis in 1977 (Table 16). The dominant forms for May were Tabellaria fenestrata v. intermedia in 1975, flagellates in 1976, and flagellates in 1977 (Table 17). In June the dominant forms were flagellates

TABLE 15. Occurrence of dominant forms in March 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
<u>Anacystis incerta</u>	0	5	0
<u>Cyclotella stelligera</u>	4	6	0
Flagellates	1	9	9
<u>Gomphosphaeria lacustris</u>	2	3	2
<u>Cyclotella</u> sp.	0	3	0
<u>Asterionella formosa</u>	0	1	0
Blue green, unknown cells	0	1	0
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	9	0	0
Centric diatom, unknown	6	0	0
<u>Stephanodiscus</u> sp.	3	0	0
<u>Fragillaria crotonensis</u>	1	0	11
Chrysophycean flagellate sp.	0	0	2
<u>Synedra filiformis</u>	0	0	11
Number of samples	9	12	12

TABLE 16. Occurrence of dominant forms in April 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
<u>Cyclotella stelligera</u>	5	1	0
Flagellates	6	0	6
<u>Fragilaria crotonensis</u>	1	6	9
<u>Gomphosphaeria lacustris</u>	1	0	0
<u>Stephanodiscus minutus</u>	1	0	0
<u>Stephanodiscus tenuis</u>	2	0	0
<u>Anacystis incerta</u>	1	3	1
<u>Asterionella formosa</u>	0	12	0
<u>Rhizosolenia gracilis</u>	0	3	0
Green colony, unknown	0	1	0
<u>Fragilaria intermedia</u> v. <u>fallax</u>	0	1	0
Chrysophycean flagellate spp.	0	0	6
<u>Synedra filiformis</u>	0	0	11
<u>Synedra ostenfeldii</u>	0	0	1
Number of samples	9	12	12

TABLE 17. Occurrence of dominant forms in May 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
<u>Anacystis incerta</u>	4	0	0
<u>Fragilaria crotonensis</u>	4	0	2
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	5	0	1
Flagellates	4	11	9
<u>Ochromonas</u> sp.	0	5	0
Centric diatom, unknown	0	1	0
<u>Oscillatoria limnetica</u>	0	1	0
<u>Rhizosolenia gracilis</u>	0	1	0
<u>Cyclotella</u> sp.	0	1	0
<u>Asterionella formosa</u>	0	1	0
<u>Stephanodiscus subtilis</u>	0	1	0
<u>Gomphosphaeria lacustris</u>	0	0	1
Chrysophycean flagellate spp.	0	0	5
<u>Synura</u> sp.	0	0	1
Number of samples	9	12	12

and Tabellaria fenestrata v. intermedia in 1975, flagellates and Dinobryon divergens in 1976, and Fragilaria crotonensis in 1977 (Table 18). In July, Cyclotella stelligera, Dictyosphaerium pulchellum, and Gloeocystis sp. were dominant in 1975, no forms were dominant in more than 50% of the total samples in 1976, and Cyclotella sp., Cyclotella comensis, and other centric diatoms were dominant in 1977 (Table 19). In August, Anacystis incerta and Chromulina parvula were dominant in 1975, Fragilaria crotonensis was dominant in 1976, and Anacystis incerta and flagellates were dominant in 1977 (Table 20). These dominant species patterns continued for the most part throughout September, October, and November. In September, Anacystis incerta and flagellates predominated in 1975, Fragilaria crotonensis did so in 1976, and Anacystis incerta and flagellates did so in 1977 (Table 21). In October, Anacystis incerta, Fragilaria crotonensis, and Gomphosphaeria lacustris were dominant in 1975, flagellates were dominant in 1976, and Anacystis incerta, Fragilaria crotonensis, and flagellates were dominant in 1977 (Table 22). During November, the dominant forms were flagellates, Anacystis incerta, Fragilaria crotonensis, and Cyclotella comensis in 1975, flagellates and Cyclotella sp. in 1976, and flagellates, Anacystis incerta, and Gomphosphaeria lacustris in 1977 (Table 23). In the month of December, centric diatoms (unknown) and Cyclotella stelligera were dominant in 1975, Fragilaria crotonensis and flagellates were dominant in 1976, and Anacystis incerta, Gomphosphaeria lacustris, and Tabellaria fenestrata v. intermedia were dominant in 1977 (Table 24).

No consistent trend of change in dominant species was observed in the monthly comparisons during the years of 1975, 1976, and 1977. However, if the data are prepared in the form of total annual occurrence for the dominant species following the trophic table compiled by Tarapchak and Stoermer (1976) using the diatom species as shown in Table 25, certain patterns emerge

TABLE 18. Occurrence of dominant forms in June 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
Flagellates	9	11	2
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	10	0	5
<u>Fragilaria capucina</u>	1	0	0
<u>Stephanodiscus tenuis</u>	2	0	0
<u>Oscillatoria limnetica</u>	2	0	0
<u>Anacystis incerta</u>	1	0	1
<u>Gomphosphaeria lacustris</u>	2	1	1
<u>Fragilaria crotonensis</u>	2	0	8
<u>Chlorella</u> sp.	0	1	0
<u>Diatoma tenue</u> v. <u>elongatum</u>	0	1	0
<u>Dinobryon bavaricum</u>	0	5	0
<u>Dinobryon divergens</u>	0	9	0
Chrysophycean flagellate spp.	0	0	2
<u>Merismopedia elegans</u>	0	0	1
<u>Cyclotella stelligera</u>	0	0	1
Number of samples	12	12	12

TABLE 19. Occurrence of dominant forms in July 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
<u>Anacystis incerta</u>	2	0	0
<u>Cyclotella</u> sp.	2	0	8
<u>Cyclotella stelligera</u>	9	0	0
<u>Dictyosphaerium pulchellum</u>	10	0	0
<u>Gloeocystis</u> sp.	9	1	0
<u>Merismopedia tenuissima</u>	1	0	0
<u>Gomphosphaeria lacustris</u>	1	0	1
Flagellates	4	0	3
Green coccoid, unknown	1	0	0
<u>Gloeocystis planctonica</u>	1	0	0
<u>Stephanodiscus</u> sp.	0	1	0
Centric diatom, unknown	0	5	0
<u>Fragilaria crotonensis</u>	0	5	10
<u>Sphaerocystis</u> sp.	0	1	0
<u>Stephanodiscus subtilis</u>	0	1	0
<u>Cyclotella comensis</u>	0	0	12
Number of samples	12	12	12



TABLE 20. Occurrence of dominant forms in August 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
<u>Anacystis incerta</u>	8	3	10
<u>Chromulina parvula</u>	9	0	0
<u>Gomphosphaeria lacustris</u>	3	2	0
<u>Cyclotella stelligera</u>	4	0	0
<u>Gloeocystis</u> sp.	5	4	0
Flagellates	3	5	6
<u>Synura</u> sp.	1	0	0
<u>Fragilaria crotonensis</u>	0	11	0
<u>Gloeocystis planctonica</u>	0	1	0
Chrysophycean flagellate sp.	0	1	5
<u>Anacystis thermalis</u>	0	0	5
<u>Crucigenia rectangularis</u>	0	0	4
<u>Cyclotella</u> sp.	0	0	1
Number of samples	12	12	12

TABLE 21. Occurrence of dominant forms in September 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
<u>Anacystis incerta</u>	11	4	12
<u>Fragilaria crotonensis</u>	2	8	0
<u>Gomphosphaeria lacustris</u>	5	0	2
Flagellates	6	1	6
<u>Anacystis thermalis</u>	4	0	0
<u>Ochromonas</u> sp.	2	0	0
<u>Gloeocystis</u> sp.	0	5	0
<u>Sphaerocystis</u> sp.	0	1	0
Chrysophycean flagellate sp.	0	1	0
Number of samples	12	12	12

TABLE 22. Occurrence of dominant forms in October 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
<u>Anacystis incerta</u>	10	5	10
<u>Fragilaria crotonensis</u>	1	2	10
Flagellates	8	9	8
<u>Gomphosphaeria lacustris</u>	6	2	3
<u>Ochromonas</u> sp.	3	0	0
<u>Cyclotella comensis</u>	0	2	0
<u>Gloeocystis planctonica</u>	0	1	0
Chrysophycean flagellate sp.	0	2	0
<u>Gloeocystis</u> sp.	0	1	1
<u>Anacystis cyanea</u>	0	0	1
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	0	0	1
Number of samples	10	12	12

TABLE 23. Occurrence of dominant forms in November 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
Flagellates	7	8	9
<u>Anacystis incerta</u>	7	5	10
Chrysophycean flagellate sp.	2	0	3
<u>Fragilaria crotonensis</u>	6	4	4
<u>Agmenellum quadruplicatum</u>	1	0	1
<u>Gomphosphaeria lacustris</u>	4	0	8
Centric diatom, unknown	2	0	0
<u>Stephanodiscus</u> sp.	1	0	0
<u>Cyclotella comensis</u>	10	0	0
<u>Cyclotella</u> sp.	0	7	0
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	0	1	0
<u>Asterionella formosa</u>	0	2	2
<u>Gloeocystis</u> sp.	0	1	0
Number of samples	12	12	12

TABLE 24. Occurrence of dominant forms in December 1975, 1976, and 1977.

Form	Occurrences		
	1975	1976	1977
Centric diatom, unknown	9	0	0
<u>Cyclotella stelligera</u>	9	0	0
<u>Ochromonas</u> sp.	3	0	0
<u>Sphaerocystis schroeteri</u>	1	0	0
<u>Gomphosphaeria lacustris</u>	1	1	7
<u>Stephanodiscus minutus</u>	1	0	0
<u>Stephanodiscus</u> sp.	1	0	0
<u>Cyclotella comensis</u>	1	1	0
<u>Cyclotella</u> sp.	1	0	0
<u>Anacystis incerta</u>	1	3	12
<u>Fragilaria crotonensis</u>	0	12	0
Flagellates	0	6	0
<u>Fragilaria capucina</u> v. <u>lanceolata</u>	0	1	0
<u>Anabaena flos-aquae</u>	0	1	1
<u>Gloeocystis planctonica</u>	0	2	0
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	0	0	6
<u>Agmenellum quadruplicatum</u>	0	0	1
<u>Anacystis thermalis</u>	0	0	2
Number of samples	11	12	12

TABLE 25. Apparent trophic preference and abundance of selected diatoms in Lake Michigan.

Selected Diatoms	Trophic Preference				
	O	M <sub>1</sub>	M <sub>2</sub>	E	EI
<u>Cyclotella compta</u> (Ehr.) Kütz.	P	M	P		
<u>Cyclotella operculata</u> (Ag.) Kütz.	M				
<u>Cyclotella ocellata</u> Pant.	M	P			
<u>Cyclotella kuetzingiana</u> Thwaites	P	M	P		
<u>Cyclotella stelligera</u> Cl. u. Grun.	P	M	P		
<u>Melosira distans</u> (Ehr.) Kütz.	M				
<u>Melosira distans</u> v. <u>alipigena</u> Grun.					M
<u>Melosira islandica</u> O. Müll.	P	M	P		
<u>Tabellaria fenestrata</u> (Lyngb.) Kütz.		P	M	P	
<u>Tabellaria flocculosa</u> (Roth) Kütz.		M	P		
<u>Rhizosolenia eriensis</u> H. L. Smith	P	M	P		
<u>Stephanodiscus transilvanicus</u> Pant.	P	M			
<u>Synedra ulna</u> v. <u>chaseana</u> Thomas	P	M			
<u>Cyclotella michiganiana</u> Skvortzow	P	M	P		
<u>Asterionella formosa</u> Hassall		P	M	P	
<u>Fragilaria crotonensis</u> Kitton		P	M	P	
<u>Stephanodiscus alpinus</u> Hust. <u>ex</u> Huber-Pestalozzi		P	M	P	
<u>Stephanodiscus minutus</u> Grun. <u>ex</u> Cleve and Moll.				P	M
<u>Stephanodiscus niagarae</u> Ehr.			P	M	
<u>Stephanodiscus hantzschii</u> Grun.			P	M	

Symbols: O, oligotrophic; M<sub>1</sub>, mesotrophic but intolerant of nutrient enrichment; M<sub>2</sub>, mesotrophic and tolerant of moderate nutrient enrichment; E, eutrophic; EI recently introduced eutrophic species; P, presence of species; and M, apparent maximum abundance of the species.

References: Holland (1968, 1969); Stoermer and Yang (1969, 1970); Holland and Beeton (1972). (Courtesy to Tarapchak and Stoermer)

TABLE 25. (continued)

Selected Diatoms	Trophic Preference				
	O	M1	M2	E	EI
<u>Synedra delicatissima</u> Lewis		P	M	P	
<u>Synedra ulna</u> v. <u>danica</u> (Kütz.) Grun.		P	M	P	
<u>Synedra ostenfeldii</u> (Krieger) A. Cleve		P	M	P	
<u>Synedra filiformis</u> Grun.		P	M	P	
<u>Amphipleura pellucida</u> Kütz.			P	M	P
<u>Melosira granulata</u> (Ehr.) Ralfs			P	M	
<u>Melosira granulata</u> v. <u>angustissima</u> o. Müll.			P	M	
<u>Fragilaria capucina</u> Desm.			P	M	
<u>Fragilaria capucina</u> v. <u>mesolepta</u> (Rabh.) Grunow			P	M	
<u>Fragilaria construens</u> (Ehr.) Grunow			P	M	
<u>Fragilaria intermedia</u> Grunow			P	M	
<u>Stephanodiscus tenuis</u> Hust.				P	M
<u>Asterionella bleakeleyi</u> Wm. Smith				P	M
<u>Diatoma tenue</u> v. <u>elongatum</u> Lyngb.				P	M
<u>Stephanodiscus binderanus</u> (Kütz.) Krieger				P	M
<u>Stephanodiscus subtilis</u> (Van Goor) A. Cleve				P	M
<u>Nitzschia dissipata</u> (Kütz.) Grun.				M	P
<u>Coscinodiscus subsalsa</u> Juhl.-Dannf.					M

Symbols: O, oligotrophic; M<sub>1</sub>, mesotrophic but intolerant of nutrient enrichment; M<sub>2</sub>, mesotrophic and tolerant of moderate nutrient enrichment; E, eutrophic; EI, recently introduced eutrophic species; P, presence of species; and M, apparent maximum abundance of the species.

References: Holland (1968, 1969); Stoermer and Yang (1969, 1970); Holland and Beeton (1972). (Courtesy to Tarapchak and Stoermer)

(Table 26). A continuous decrease in occurrence of mesotrophic species not tolerant of nutrient enrichment can be noted; such occurrences go from 31 in 1975 to 7 in 1976, and then to 1 in 1977. On the other hand, there is an increase in occurrences of mesotrophic species which are tolerant of moderate nutrient enrichment; 41 in 1975, 65 in 1976, and 94 in 1977 (Table 27). This indicates a continuing eutrophication of Lake Michigan.

Along with the above accountable changes in the system, the following changes have been observed: 1) a consistent increase in the occurrence of flagellates; 2) a large increase in occurrence and abundance of the blue-green alga Anacystis incerta in 1977; and 3) a significant increase in occurrence of chrysophycean flagellates from 2 in 1975 to 4 in 1976, and to 23 in 1977 (Table 28). The mechanisms which cause these changes are presently unknown, and from the information available it is difficult to offer a good explanation; nevertheless, a further study of these species may yield considerable dividends in determining the factors influencing these changes.

#### Numbers of Forms, Diversity, and Redundancy --

When working with complex and variable assemblages of phytoplankton such as those appearing in entrainment samples from the nearshore of Lake Michigan, it is advantageous to seek some quantitative measure of the distribution of populations within the various assemblages; such measures can furnish information for assessing changes in community structure. The quantitative measures employed in this study are the number of species, diversity index, and redundancy.



Table 26. The annual occurrence of selected dominant diatom forms in 1975, 1976, and 1977. (Refer to Table 25 for definitions of symbols M1, M2, and E).

	1975	1976	1977
<u>Stephanodiscus minutus</u> (E)	2	0	0
<u>Fragilaria capucina</u> (E)	1	1	0
<u>Stephanodiscus tenuis</u> (E)	4	1	0
<u>Stephanodiscus subtilis</u> (E)	0	2	0
<u>Diatoma tenue</u> v. <u>elongatum</u> (E)	0	1	0
<u>Fragilaria crotonensis</u> (M2)	17	48	56
<u>Tabellaria fenestrata</u> v. <u>intermedia</u> (M2)	24	1	14
<u>Synedra filiformis</u> (M2)	0	0	22
<u>Asterionella formosa</u> (M2)	0	16	2
<u>Cyclotella stelligera</u> (M1)	31	7	1
<u>Cyclotella</u> sp.	3	12	9
<u>Cyclotella comensis</u>	11	3	12

TABLE 27. The annual occurrence of dominant diatom forms with respect to each trophic level for 1975, 1976, and 1977. (Refer to Table 25 for definitions of symbols M1, M2, and E).

	1975	1976	1977
M1	31	7	1
M2	41	65	94
E	7	5	0

TABLE 28. The annual occurrence of dominant blue-green algae and flagellates in 1975, 1976, and 1977.

	1975	1976	1977
Flagellates	41	49	56
<u>Anacystis incerta</u>	45	28	56
Chrysophycean flagellate	2	4	23
<u>Gomphosphaeria lacustris</u>	25	8	25

The diversity index is calculated using the formula presented by Wilhm and Dorris (1968):

$$\bar{d} = - \sum_{i=1}^S (n_i/n) \log_2 (n_i/n)$$

where S is the number of species, n is the total number of phytoplankton in cell/mL, and  $n_i$  is the number of phytoplankton of the  $i$ th species. Since not all forms encountered can be identified to the species level, the diversity index presented may differ somewhat from the true diversity measure; one must view this with caution.

Redundancy is a measure of the dominance of one or a few species within a population assemblage. As presented by Wilhm and Dorris (1968), it is:

$$r = \frac{\bar{d}_{\max} - \bar{d}}{\bar{d}_{\max} - \bar{d}_{\min}}$$

where  $\bar{d}$  is the diversity of a community as calculated above,  $\bar{d}_{\max}$  is the maximum diversity for the community, and  $\bar{d}_{\min}$  is the minimum diversity for the community.  $\bar{d}_{\max}$  and  $\bar{d}_{\min}$  are computed as follows:

$$\bar{d}_{\max} = (1/n)(\log_2 n! - S \log_2 [n/S]!)$$

$$\bar{d}_{\min} = (1/n)(\log_2 n! - S \log_2 [n-(S-1)]!)$$

The possible values of r vary in a range between 0 and 1. When an r equals 0, it indicates that all the species encountered in a community have the same abundance, whereas when an r equals 1, it implies that one species dominates a community. As shown in the formula, this value is derived from the measures of species number, abundance, and diversity.

The number of forms in the 1977 entrainment samples showed a bimodal variation, with its primary peak in June and its secondary peak in September (Table 29). The number of forms varies in a range from 46 to 64; the minimum and maximum number of forms correspond with the months of May and June respectively, during which the largest changes in species occurred. This marked alteration in species number is seen not only between May and June but also between August and September.

Species diversity and fluctuations have long been an important issue, and many theories attempt to explain this phenomenon. The one offering the simplest and best explanation to the system being studied was proposed by Moss (1973) who explained that different species begin to divide at different times of the year, dependent on their specific requirements for light, temperature, and nutrient types and levels. Most of these species are probably present in at least very small numbers throughout the year, and from these inocula larger populations can develop. After growth of a large population, decline occurs as the number of cells returns to the inoculum level. Population size depends on the balance between growth and concomitant loss by sinking, parasitism, and grazing. After the peak population has been reached, there is a rapid initial decline. As some populations decline, others grow, and with time the complexity of overlap increases, leading to progressively greater diversity. This hypothesis seems to explain why the number of species increased rapidly in June and September after a rapid initial decline in species in the months of May and August. But this hypothesis alone cannot fully illustrate all the changes in species in this system. In part the increase in species number in summer can be attributed to upwelling which makes available hypolimnetic nutrients, particularly orthophosphate and silica, which stimulate the growth of some species that would not otherwise grow (Rossmann et al. 1979).

TABLE 29. Comparison of the number of forms of phytoplankton for 1975, 1976 and 1977. Standard errors are included in parentheses.

Month	1975		1976		1977	
	Replicates	Forms	Replicates	Forms	Replicates	Forms
January	--1	--1	11	59.4(2.79)	--1	--1
February	--1	51.1(1.90)	12	57.3(1.64)	--1	--1
March	9	51.7(1.89)	12	59.3(1.59)	12	52.9(2.36)
April	9	48.3(1.38)	12	56.1(1.43)	12	55.5(3.37)
May	9	47.4(1.78)	12	60.3(2.84)	12	46.4(2.91)
June	12	49.2(1.77)	12	65.8(1.77)	12	64.1(3.59)
July	12	51.6(.892)	12	87.3(3.78)	12	57.7(2.64)
August	12	44.5(2.32)	12	53.4(3.31)	12	46.9(2.26)
September	10	44.1(3.12)	12	84.8(4.30)	12	60.3(2.75)
October	12	54.0(2.18)	12	58.8(2.77)	12	52.3(2.60)
November	12	50.3(2.11)	12	57.2(1.74)	12	46.6(1.85)
December	11	50.8(1.74)	12	56.5(1.81)	12	56.4(2.52)
Yearly Mean		49.4(.969)		63.1(3.25)		53.9(1.92)

<sup>1</sup> Samples were not collected where dashes appear. Samples have not yet been analyzed where blanks appear.

The diversity index is an estimate of the structure of communities. It measures the degree to which individuals are distributed among the species in a community and is determined by the number of species and the degree of apportionment of individuals among species. For example, a high diversity index can signify (1) large numbers of species, (2) a high degree of apportionment of individuals among species, or (3) both large numbers of species and the codominancy of many species. In 1977, diversity reached its maximum in June and its minimum in May, corresponding with the values of 4.62 and 2.98, respectively (Table 30). The maximum and minimum coincided precisely with the time when the maximum and minimum number of species occurred. This coincidence does not always occur; frequently a large number of species does not result in a high diversity index. This is because the diversity index depends not only on the number of species but also on the codominancy of many species. Therefore, it is not uncommon that a system with a large number of species, but in which one species is dominant, has a relatively low diversity value. In fact, the case of September, 1977, can precisely illustrate this situation: a large number of species was encountered, but only one species, Anacystis incerta, was predominant at the time. Despite this exception, species number has often been significantly correlated with the diversity indices in this study (Table 31). The diversity index normally ranges from values slightly greater than zero in bloom situations to values as high as 4.5 (Tarapchak and Stoermer 1976). In this system, however, the monthly mean index of the entrained samples varies from 2.98 to 4.62 with an annual mean of 3.79. According to the Margalef classification (1968), the ranges of values corresponding to trophic states are as follows: oligotrophic,  $>3.5$ ; mesotrophic, 2.5 to 3.5; and eutrophic,  $<2.5$ . This classification seems to indicate that the region studied is still far from a state in which the thermal

TABLE 30. Comparison of phytoplankton diversities for 1975, 1976, and 1977. Standard errors are included in parentheses.

Month	1975		1976		1977	
	Replicates	Diversity	Replicates	Diversity	Replicates	Diversity
January	--1	--1	11	4.29(.0457)	--1	--1
February	9	4.35(.0473)	12	4.47(.0591)	--1	--1
March	9	4.30(.0544)	12	4.34(0.633)	12	3.85(.0680)
April	9	4.21(.0569)	12	4.30(.0446)	12	4.36(.0872)
May	9	3.76(.228)	12	4.37(.112)	12	2.98(.186 )
June	12	4.17(.0809)	12	4.67(.0616)	12	4.62(.0836)
July	12	3.93(.0654)	12	5.08(.0380)	12	4.00(.0564)
August	12	3.58(.163)	12	3.50(.114)	12	3.29(.161 )
September	10	3.36(.189)	12	4.92(.0973)	12	3.29(.109 )
October	12	3.96(.138)	12	4.48(.0823)	12	4.00(.0764)
November	12	4.02(.119)	12	3.97(.0608)	12	3.69(.0945)
December	11	3.83(.0982)	12	3.96(.0963)	12	3.82(.113 )
Yearly Mean		3.95(.0924)		4.36(.124)		3.79(.159 )

<sup>1</sup> Samples were not collected where dashes appear. Samples have not yet been analyzed where blanks appear.

TABLE 31. Correlation matrix for variables important to or describing the phytoplankton community.

N= 120 DF= 118 R@ .0500= .1793 R@ .0100= .2343					
SPECIES	1.0000				
ABUNDANCE	.0172	1.0000			
DIVERSITY	.4751	-.0170	1.0000		
TEMPERATURE	.0276	-.2243	-.1427	1.0000	
REDUNDANCY	-.1564	.0162	-.9418	.1646	1.0000
	SPECIES	ABUNDANCE	DIVERSITY	TEMPERATURE	REDUNDANCY

impact drastically decreases species survival and thereby reduces the diversity index significantly.

Redundancy was low in April and June and high in May, August, and September (Table 32). It reached its maximum and minimum in May and June, respectively. The high redundancy values in May, August, and September coincided with a community constituted predominantly of one species; during the month of May, Flagilaria crotonensis predominated, and during August and September, Anacystis incerta predominated. The minimum redundancy in June shows the codominacy of a large number of species, which may be attributed both to upwelling and to the occurrence of significant species overlap in phytoplankton succession.

When the species numbers and the diversity and redundancy indices are compared annually, the number of species is high in 1976 relative to 1975 and 1977, and the diversity index is also at its highest in 1976; the redundancy index, however, has its maximum in 1977 and its minimum in 1976. There is no observable trend for these estimates in the years considered.

#### Numbers and Biomass of Phytoplankton Passing Through the Plant --

One of the major stress factors unique to entrained phytoplankton is the artificially elevated temperature in the condenser through which entrained phytoplankton must pass. The intake water temperature during the year of 1977 varied from 1°C to over 23°C; after the water had passed through the cooling system, its temperature at the discharge was about 10°C higher. In the summer, the discharge water temperature approached 34°C, the temperature suggested by Patrick (1969) as having a harmful effect on algae. Because of possible harmful effects on algae, the numbers and biomass of phytoplankton passing through the condenser and the possible effect of this impact on phytoplankton

TABLE 32. Comparison of phytoplankton redundancies for 1975, 1976, and 1977. Standard errors are included in parentheses.

Month	1975		1976		1977	
	Replicates	Redundancy	Replicates	Redundancy	Replicates	Redundancy
January	--1	--1	11	.270(.011)	--1	----
February	9	.230(.009)	12	.231(.011)	--1	----
March	9	.243(.008)	12	.263(.011)	12	.329(.008)
April	9	.246(.009)	12	.260(.007)	12	.244(.006)
May	9	.327(.054)	12	.259(.015)	12	.474(.030)
June	12	.258(.010)	12	.223(.010)	12	.223(.011)
July	12	.310(.011)	12	.210(.008)	12	.318(.012)
August	12	.353(.026)	12	.393(.017)	12	.411(.034)
September	10	.389(.029)	12	.227(.013)	12	.457(.022)
October	12	.317(.021)	12	.322(.014)	12	.335(.015)
November	12	.289(.019)	12	.322(.011)	12	.348(.019)
December	11	.325(.017)	12	.322(.018)	12	.348(.019)
Yearly Mean		299(.0152)		.268(.0154)		.344(.0262)

<sup>1</sup> Samples were not collected where dashes appear. Samples have not yet been analyzed where blanks appear.



were assessed in this study.

The plant pumped water at an average rate of  $2700 \text{ m}^3\text{min}^{-1}$  during most of the sampling period. Using the mean monthly total of phytoplankton densities, an approximate number of phytoplankton passing through the plant for each month can be estimated. The weight of the phytoplankton is then computed using the conversion coefficient of  $0.57 \times 10^{-9} \text{ gm}$  as the average weight of a phytoplankton cell (Ayers and Seibel 1973). Using these methods, an estimate of  $2.68 \times 10^{18}$  phytoplankton cells or  $1.53 \times 10^9 \text{ gm}$  of phytoplankton was obtained for total entrainment during March through December of 1977 (Table 33). Since the above estimates began in March, the values do not cover a full calendar year. Therefore, it would not be appropriate to make annual comparisons of the total entrained phytoplankton in numbers or weight. Furthermore, the above estimates were based on the assumption that the plant was operating 100% of the time and that no recirculation of discharge water occurred. Thus, the monthly estimate represents a somewhat inflated value for the number and weight of phytoplankton passing through the plant during each month.

When the entrained phytoplankton of 1977 were compared to those of 1976, there were significant reductions in numbers and weight entrained during May, July, September, and December in 1977 (Table 33). This reduction is apparently associated with the decrease in the phytoplankton population density in the nearshore region of Lake Michigan.

#### OCCURRENCES OF DOMINANT PHYTOPLANKTON SPECIES

Organisms entrained by a power plant are exposed to rapid temperature changes. A difference of about  $10^\circ\text{C}$  has frequently been noted between the

TABLE 33. Phytoplankton entrained by the plant during 1976 and 1977. (Mean and standard deviation are shown for 1977 data, but only mean for 1976 data; - - - indicates no data).

Month	Numbers Entrained		Weight Entrained (gms)	
	1976	1977	1976	1977
January	4.25 x 10 <sup>17</sup>	- - - - -	2.42 x 10 <sup>8</sup>	- - - - -
February	1.59 x 10 <sup>17</sup>	- - - - -	9.06 x 10 <sup>7</sup>	- - - - -
March	2.22 x 10 <sup>17</sup>	2.87 x 10 <sup>17</sup> (0.81 x 10 <sup>17</sup> )	1.27 x 10 <sup>8</sup>	1.64 x 10 <sup>8</sup> (0.46 x 10 <sup>8</sup> )
April	3.49 x 10 <sup>17</sup>	4.32 x 10 <sup>17</sup> (1.30 x 10 <sup>17</sup> )	1.99 x 10 <sup>8</sup>	2.46 x 10 <sup>8</sup> (0.74 x 10 <sup>8</sup> )
May	5.45 x 10 <sup>17</sup>	2.13 x 10 <sup>17</sup> (0.85 x 10 <sup>17</sup> )	3.11 x 10 <sup>8</sup>	1.21 x 10 <sup>8</sup> (0.48 x 10 <sup>8</sup> )
June	1.81 x 10 <sup>17</sup>	1.83 x 10 <sup>17</sup> (0.96 x 10 <sup>17</sup> )	1.04 x 10 <sup>8</sup>	1.03 x 10 <sup>8</sup> (0.55 x 10 <sup>8</sup> )
July	9.57 x 10 <sup>17</sup>	2.53 x 10 <sup>17</sup> (0.60 x 10 <sup>17</sup> )	5.45 x 10 <sup>8</sup>	1.44 x 10 <sup>8</sup> (0.34 x 10 <sup>8</sup> )
August	3.79 x 10 <sup>17</sup>	2.48 x 10 <sup>17</sup> (1.17 x 10 <sup>17</sup> )	2.16 x 10 <sup>8</sup>	1.41 x 10 <sup>8</sup> (0.76 x 10 <sup>8</sup> )
September	5.89 x 10 <sup>17</sup>	1.88 x 10 <sup>17</sup> (0.53 x 10 <sup>17</sup> )	3.36 x 10 <sup>8</sup>	1.07 x 10 <sup>8</sup> (0.30 x 10 <sup>8</sup> )
October	3.28 x 10 <sup>17</sup>	3.07 x 10 <sup>17</sup> (1.15 x 10 <sup>17</sup> )	1.87 x 10 <sup>8</sup>	1.75 x 10 <sup>8</sup> (0.66 x 10 <sup>8</sup> )
November	3.60 x 10 <sup>17</sup>	3.56 x 10 <sup>17</sup> (1.64 x 10 <sup>17</sup> )	2.05 x 10 <sup>8</sup>	2.03 x 10 <sup>8</sup> (0.93 x 10 <sup>8</sup> )
December	3.46 x 10 <sup>17</sup>	2.11 x 10 <sup>17</sup> (0.76 x 10 <sup>17</sup> )	1.97 x 10 <sup>8</sup>	1.20 x 10 <sup>8</sup> (0.43 x 10 <sup>8</sup> )
Total	4.84 x 10 <sup>18</sup>	2.68 x 10 <sup>18</sup>	2.76 x 10 <sup>9</sup>	1.53 x 10 <sup>9</sup>

intake and discharge waters in our study. This increase in temperature during entrainment may create a stress condition for planktonic populations. A preliminary assessment of the extent to which there may be an impact due to the power plant waste heat is made in this section.

Patrick (1971) indicated that a 15C° temperature rise will not be especially detrimental to diatoms that are acclimated at 5°C, but the same shock effect on the same diatoms at 25°C can cause great damage and is often lethal. Her study illustrated the important point that every organism has an upper and a lower tolerance limit. This tolerance limit is not constant for organisms and can be modified by the ability of organisms to physiologically adapt to different conditions. This limit may also be modified to some extent by the environmental conditions in the system. When the ambient temperature is near the middle of an organism's tolerance range, a minor violation of its tolerance limit would have no significant impact on the organism or it may accelerate the rate at which the phytoplankton species goes into a resting phase (Patrick 1971). When the ambient condition is close to the tolerance limit, a rise in temperature which greatly exceeds the tolerance limit can frequently produce a lethal effect.

To establish the conditions of occurrence of the dominant phytoplankton species, concentration and temperature data have been combined. The characteristic occurrence of dominant species collected at the Cook Plant from 1975 through 1977 has been compiled. This permits the establishment of the months of maximum abundance and occurrence of each species. Temperature data are combined with the occurrences of each species to establish temperatures of occurrence and maximum abundance.

### Monthly Variations

#### Anabaena flos-aquae--

This filamentous blue-green alga had approximately the same annual population density for the three years in question (Figures 2-4). The seasonal fluctuations were also fairly consistent. The population was maintained at a low level until June or July when an increase occurred, there was a sharp decrease in August, cell numbers increased again in September and October, and they decreased in November. In December 1976 and 1977, contradicting other established data (Stoermer and Ladewski 1976, Findenegg 1943), Anabaena flos-aquae populations increased. This was possibly due to the recycling of water by the power plant to prevent ice formation.

#### Anacystis incerta--

There were some consistent annual fluctuations which may be observed in these data (Figures 5-7). Each year there was a spring bloom of varying intensity. This was followed by a summer decrease in cell numbers and then a large fall bloom. The large population in the fall is typical of blue-green algae (Stoermer et al. 1974). The variations which exist in the seasonal patterns may in part be explained by the delayed effects of the upwelling which occurred in July 1976 and 1977. Although the total cell numbers were not constant from year to year (cells/mL decreased approximately 50% in 1976 and increased 50% above the 1975 levels in 1977) the variations appear to be due either to a natural oscillation in the population or to patchiness due to sampling colonies with a large number of cells.

## ANABAENA FLOS-AQUAE

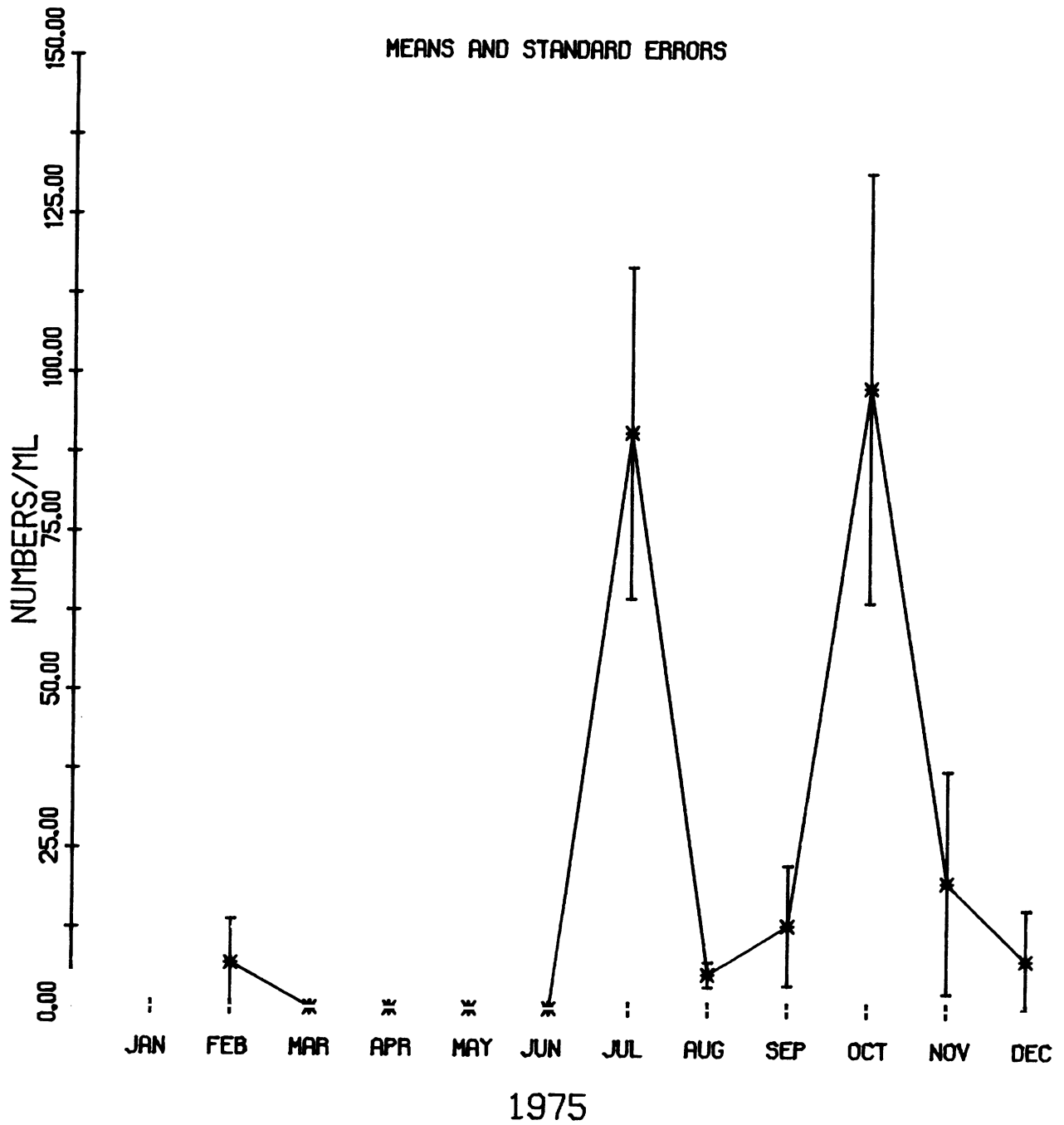


FIG. 2. Variation of Anabaena flos-aquae numbers during 1975.

# ANABAENA FLOS-AQUAE

MEANS AND STANDARD ERRORS

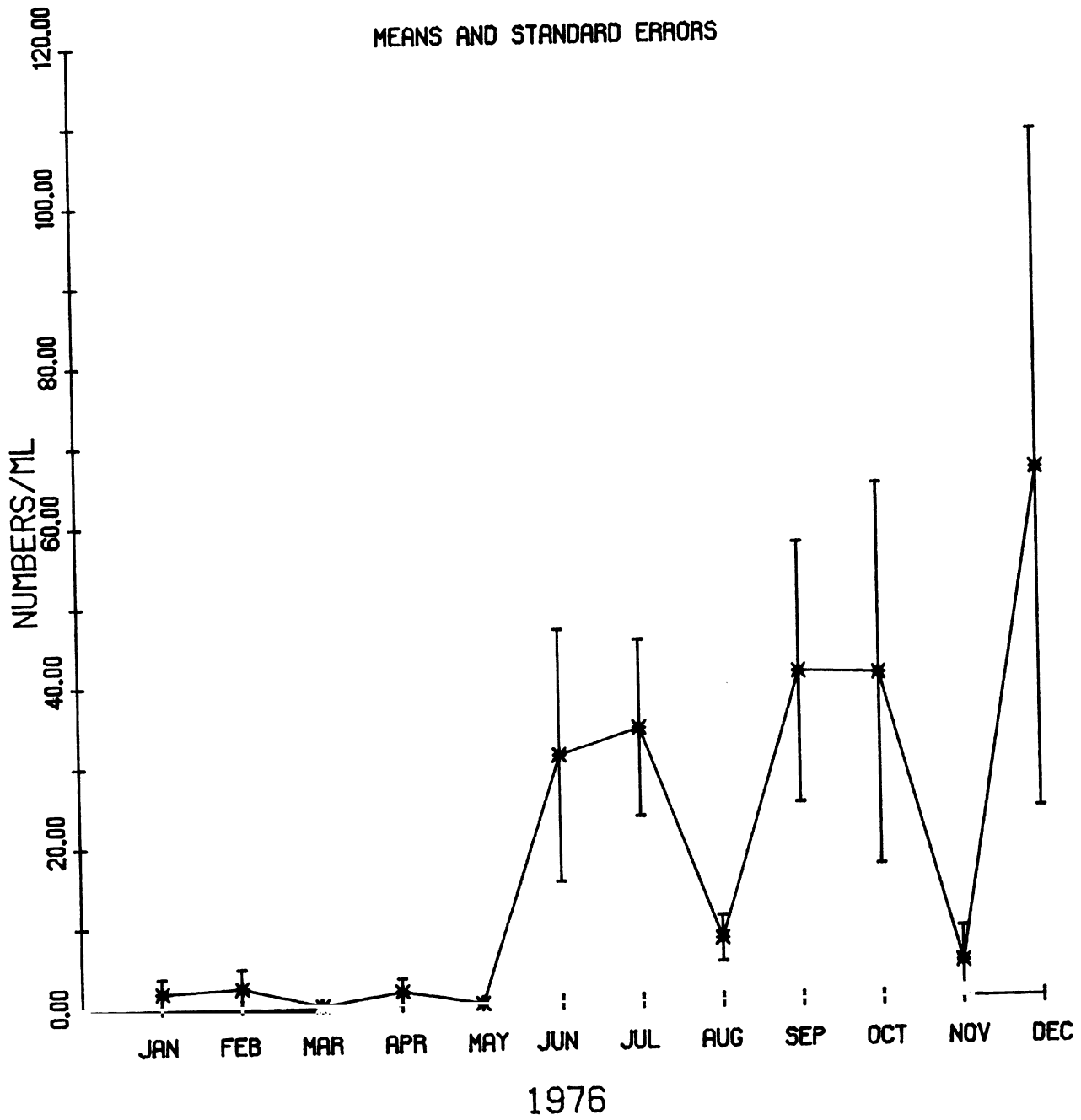


FIG. 3. Variation of *Anabaena flos-aquae* numbers during 1976.

## ANABAENA FLOS-AQUAE

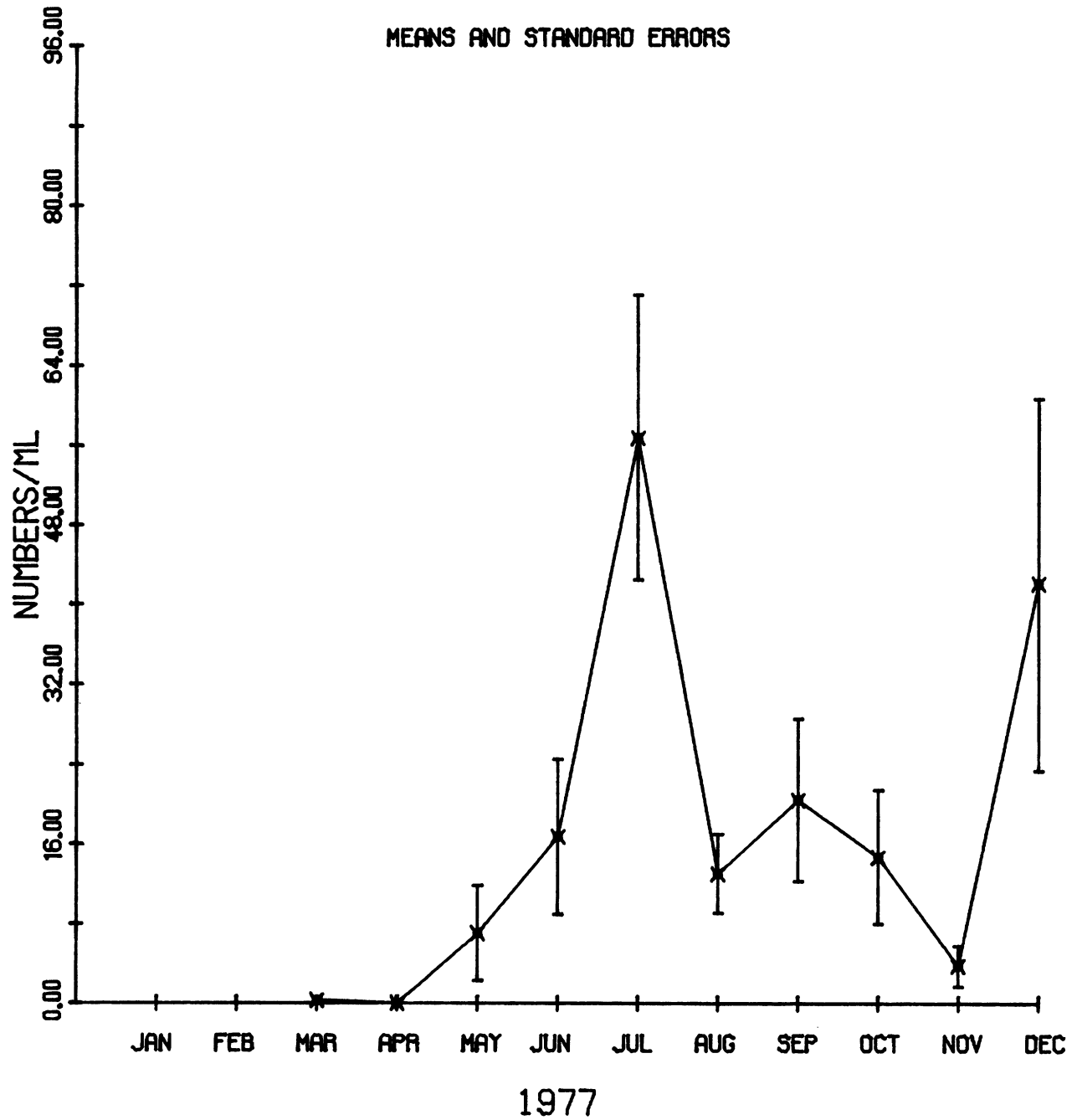


FIG. 4. Variation of Anabaena flos-aquae numbers during 1977.

## ANACYSTIS INCERTA

MEANS AND STANDARD ERRORS

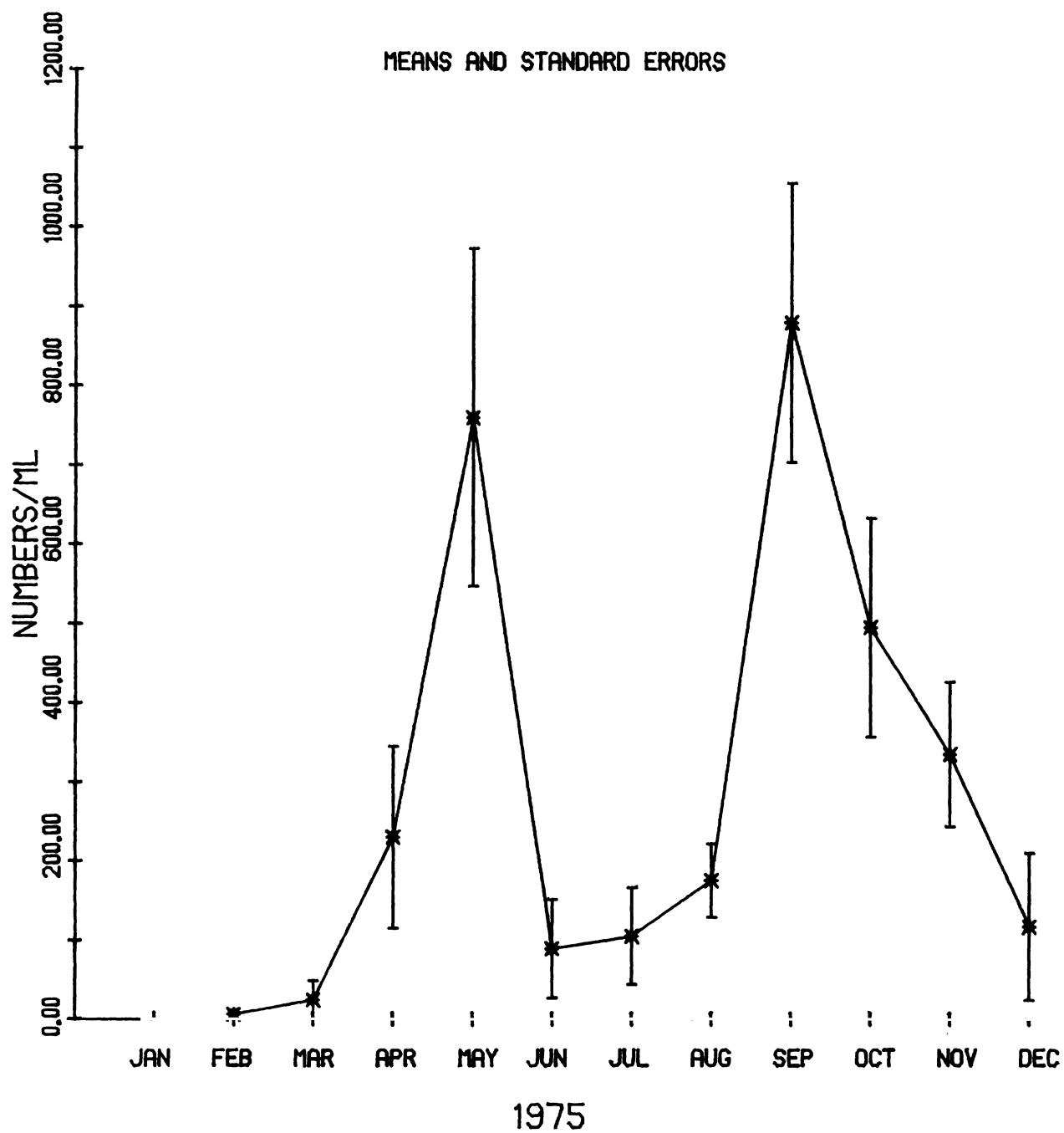


FIG. 5. Variation of Anacystis incerta numbers during 1975.



# ANACYSTIS INCERTA

MEANS AND STANDARD ERRORS

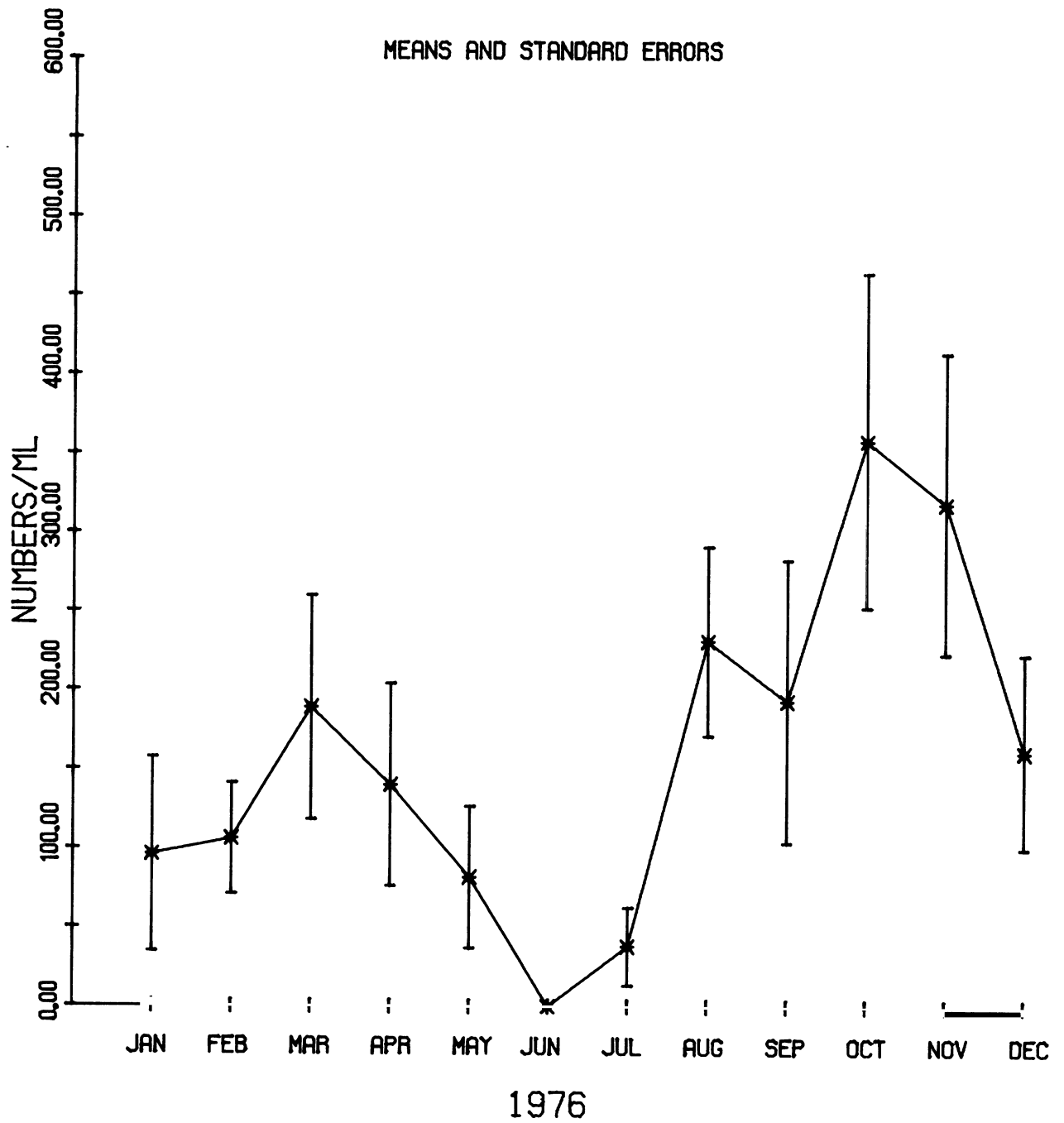


FIG. 6. Variation of Anacystis incerta numbers during 1976.

# ANACYSTIS INCERTA

MEANS AND STANDARD ERRORS

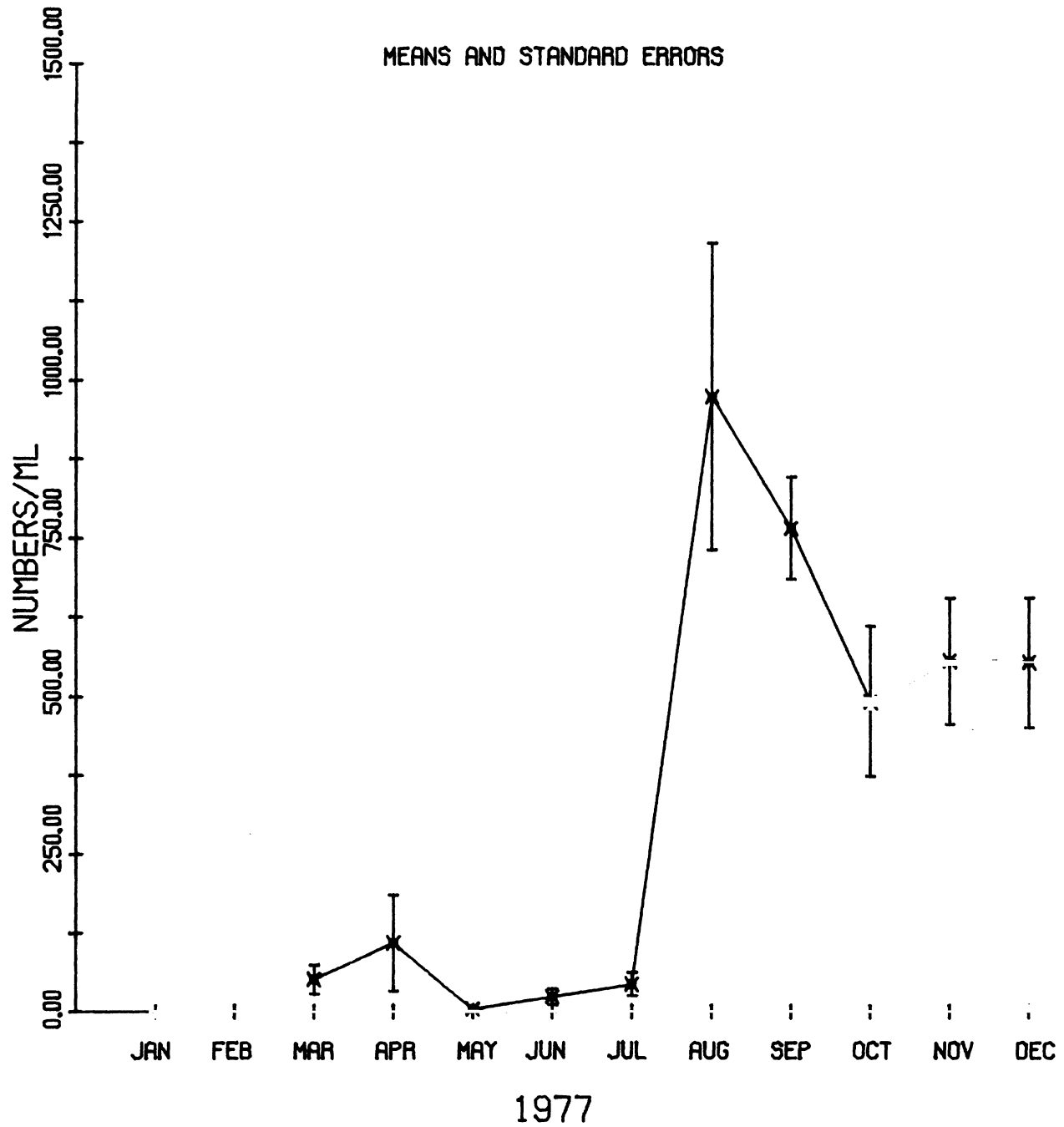


FIG. 7. Variation of *Anacystis incerta* numbers during 1977.

Anacystis thermalis--

In 1975, 1976, and 1977 the Anacystis thermalis population was maintained at very low levels until the late summer or early fall (Figures 8-10). The number of cells varied from year to year with a small decline in 1976 and a large increase in 1977. It would be premature to conclude from this study that the population of this alga is increasing in the intake area. Future data will have to be considered to see if the upward trend continues. Once again increases in December are probably due to some effect of the warmer discharge water near the sampling sites.

Anacystis cyanea--

This species was dominant only in October 1977 (Figure 11). The large standard deviation associated with this peak is indicative of counting small, multi-celled colonies.

Gomphosphaeria lacustris--

There was very little consistency within the population of this alga during 1975-1977 (Figures 12-14). 1975 was characterized by three peak abundances, with the largest in the fall. The population of 1976 oscillated quite markedly each month, while the only substantial abundance in 1977 occurred in the fall. There was no consistent upward or downward trend in cell numbers for the 3-year period. The large amount of patchiness found in sampling multi-celled colonies may also apply.

## ANACYSTIS THERMALIS

MEANS AND STANDARD ERRORS

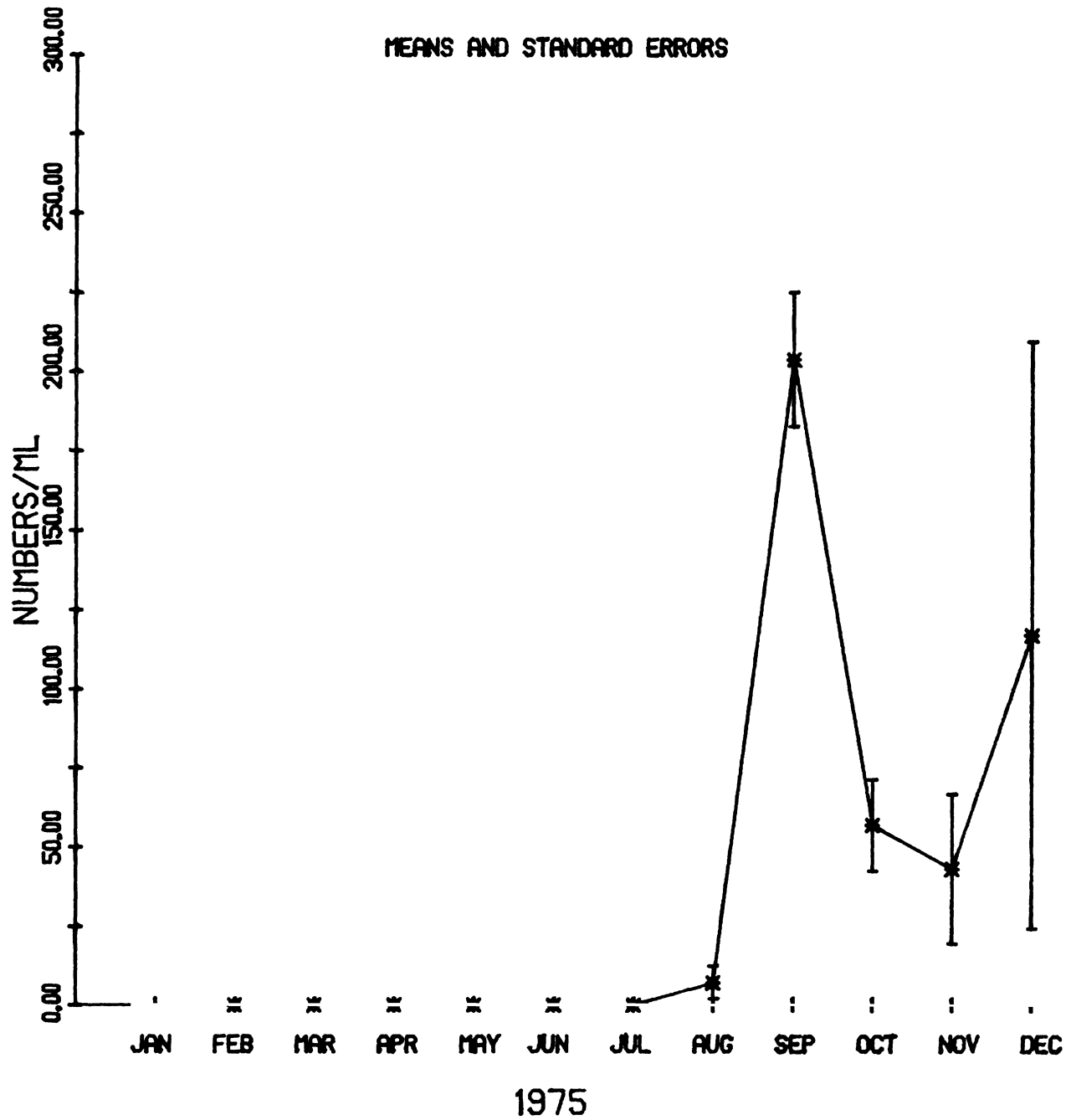


FIG. 8. Variation of Anacystis thermalis numbers during 1975.

# ANACYSTIS THERMALIS

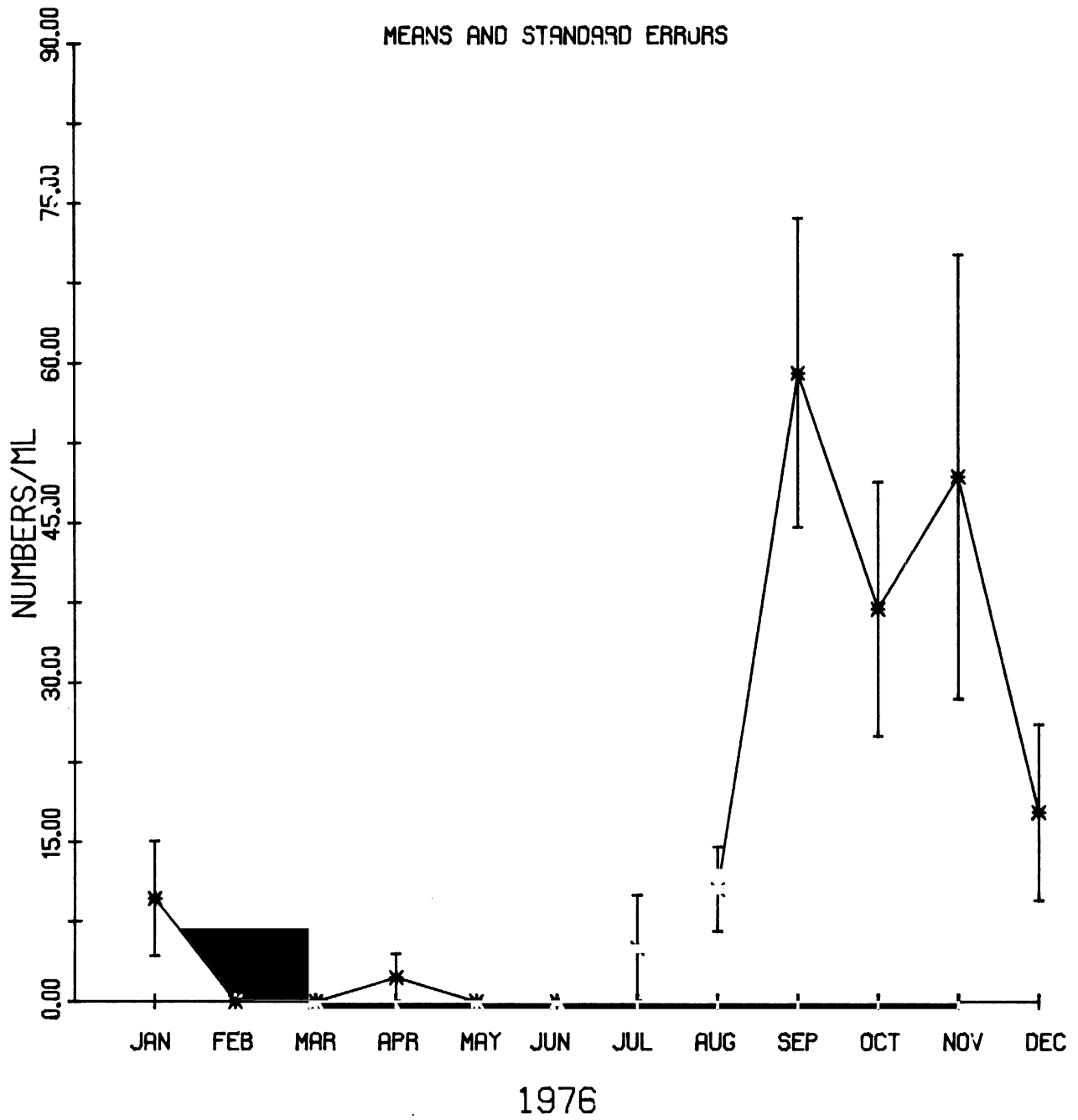


FIG. 9. Variation of Anacystis thermalis numbers during 1976.

# ANACYSTIS THERMALIS

MEANS AND STANDARD ERRORS

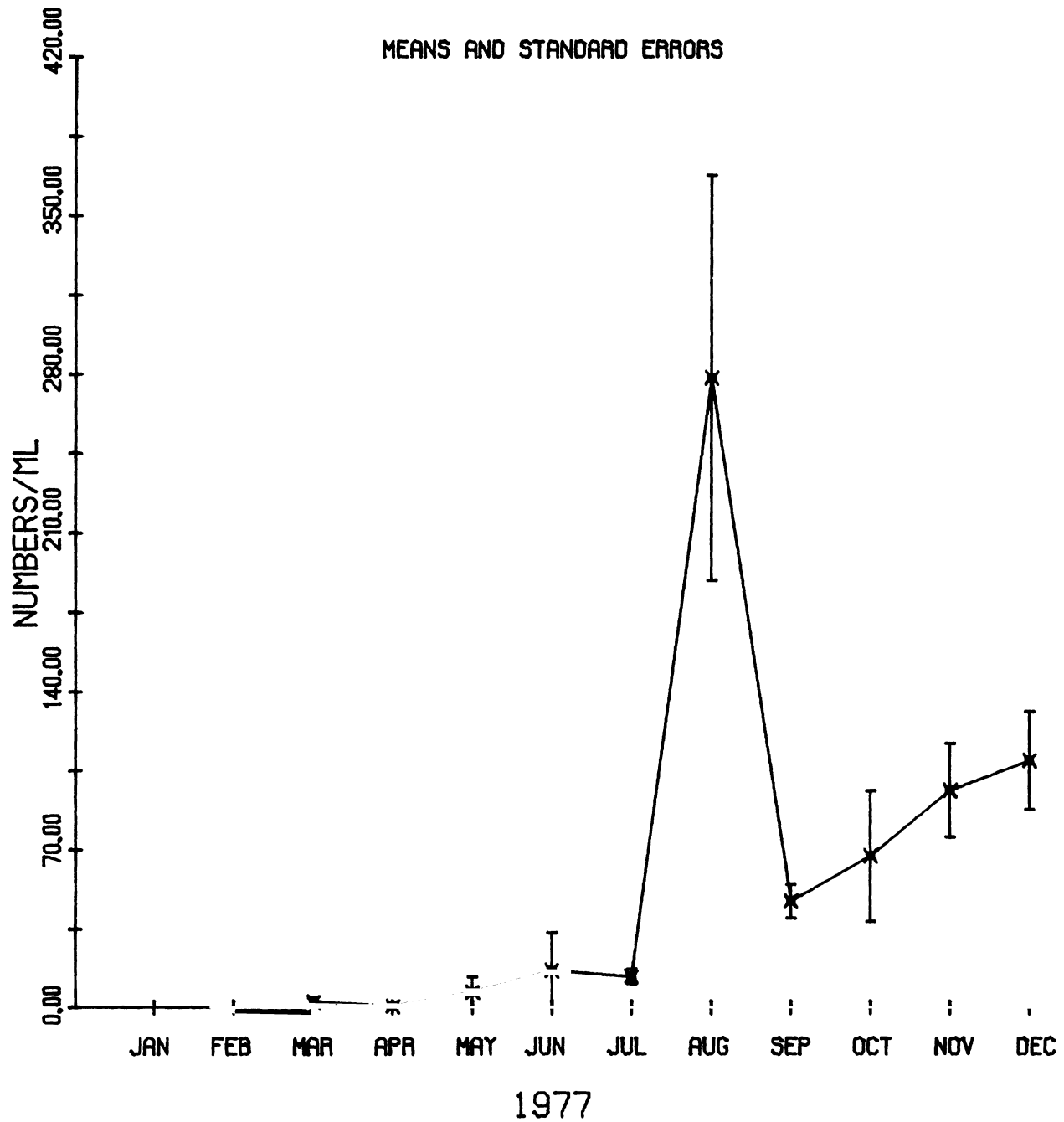


FIG. 10. Variation of Anacystis thermalis numbers during 1977.

# ANACYSTIS CYANEA

MEANS AND STANDARD ERRORS

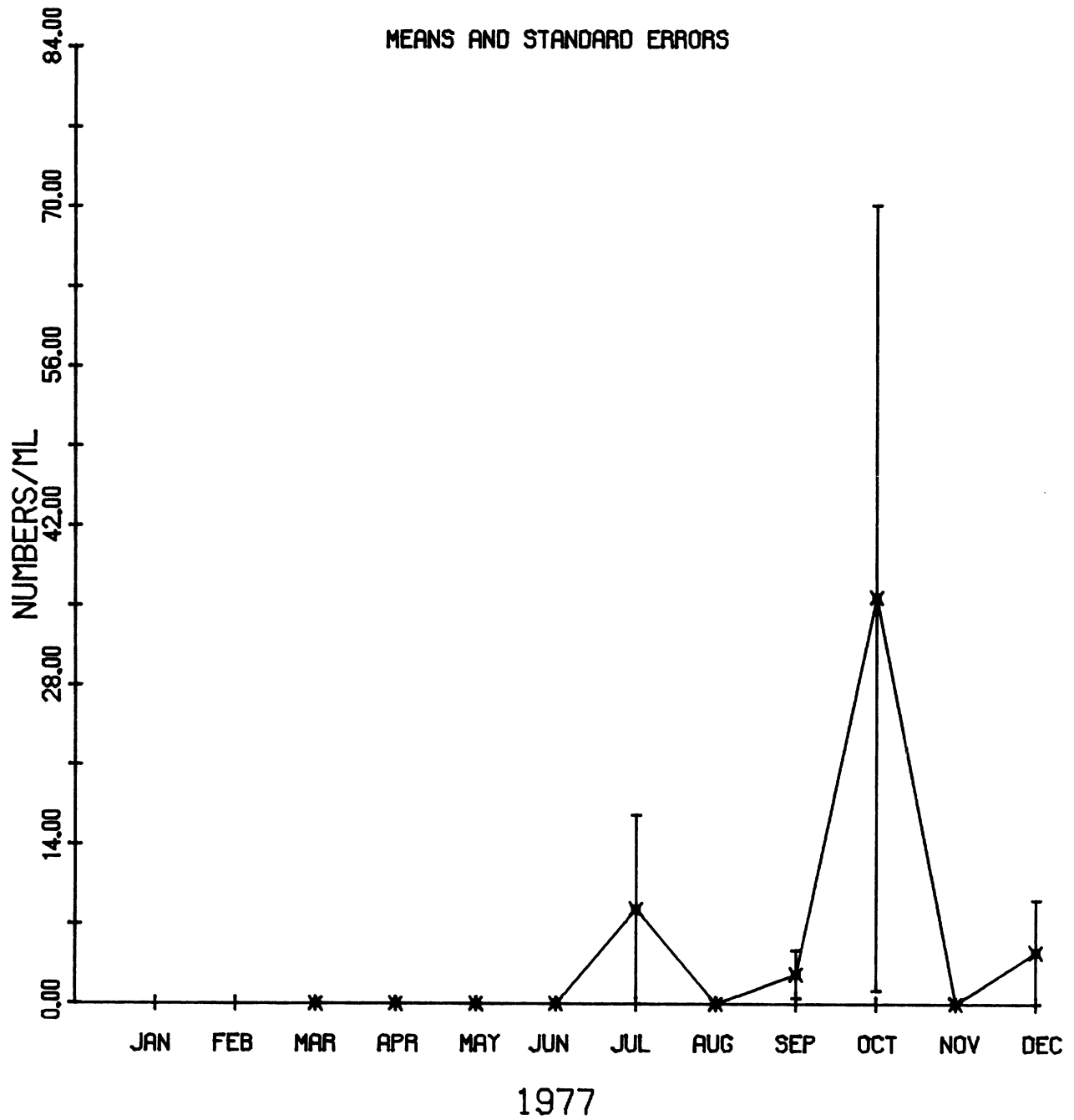


FIG. 11. Variation of *Anacystis cyanea* numbers during 1977.

## GOMPHOSPHAERIA LACUSTRIS

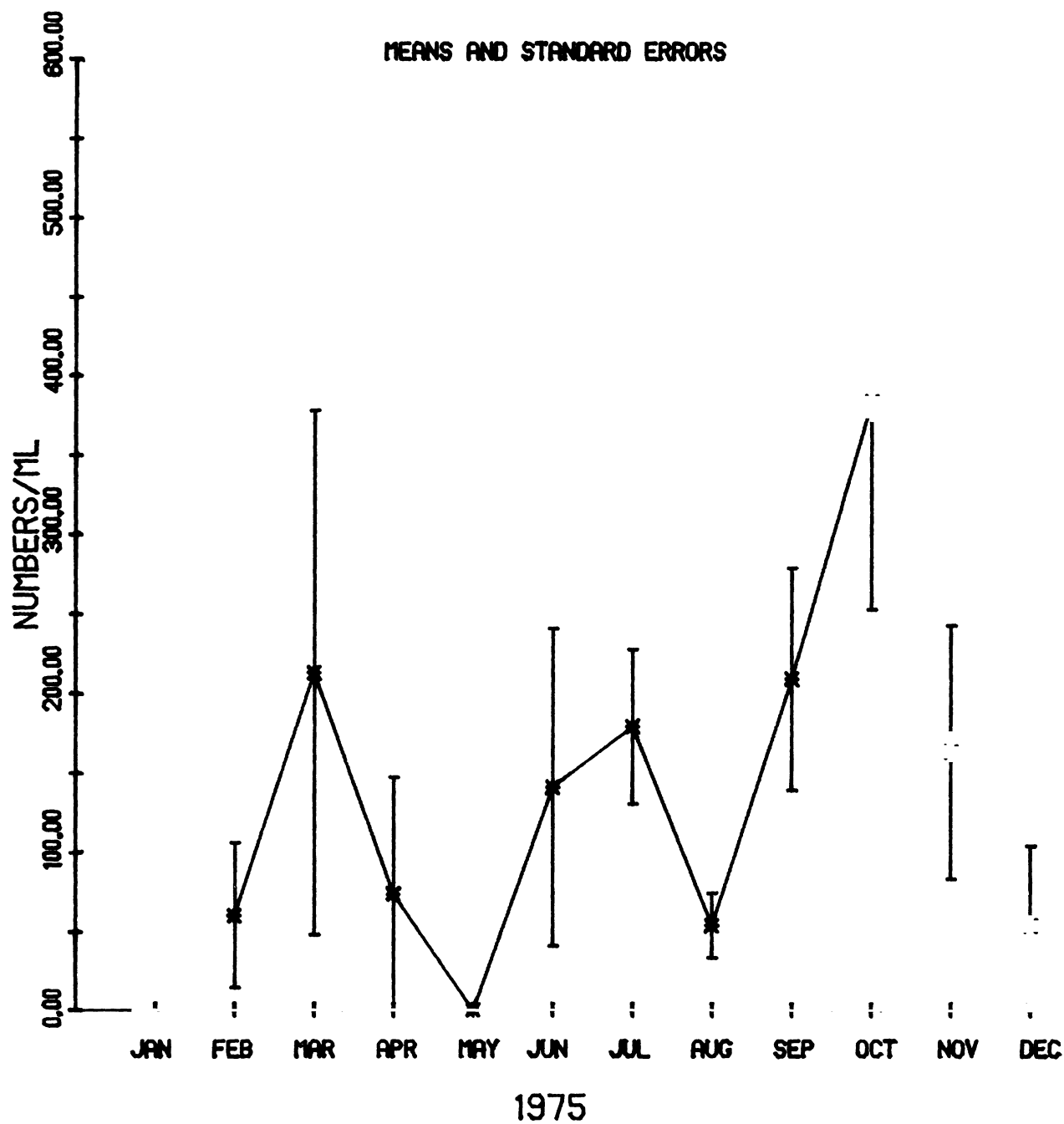


FIG. 12. Variation of Gomphosphaeria lacustris numbers during 1975.



## GOMPHOSPHAERIA LACUSTRIS

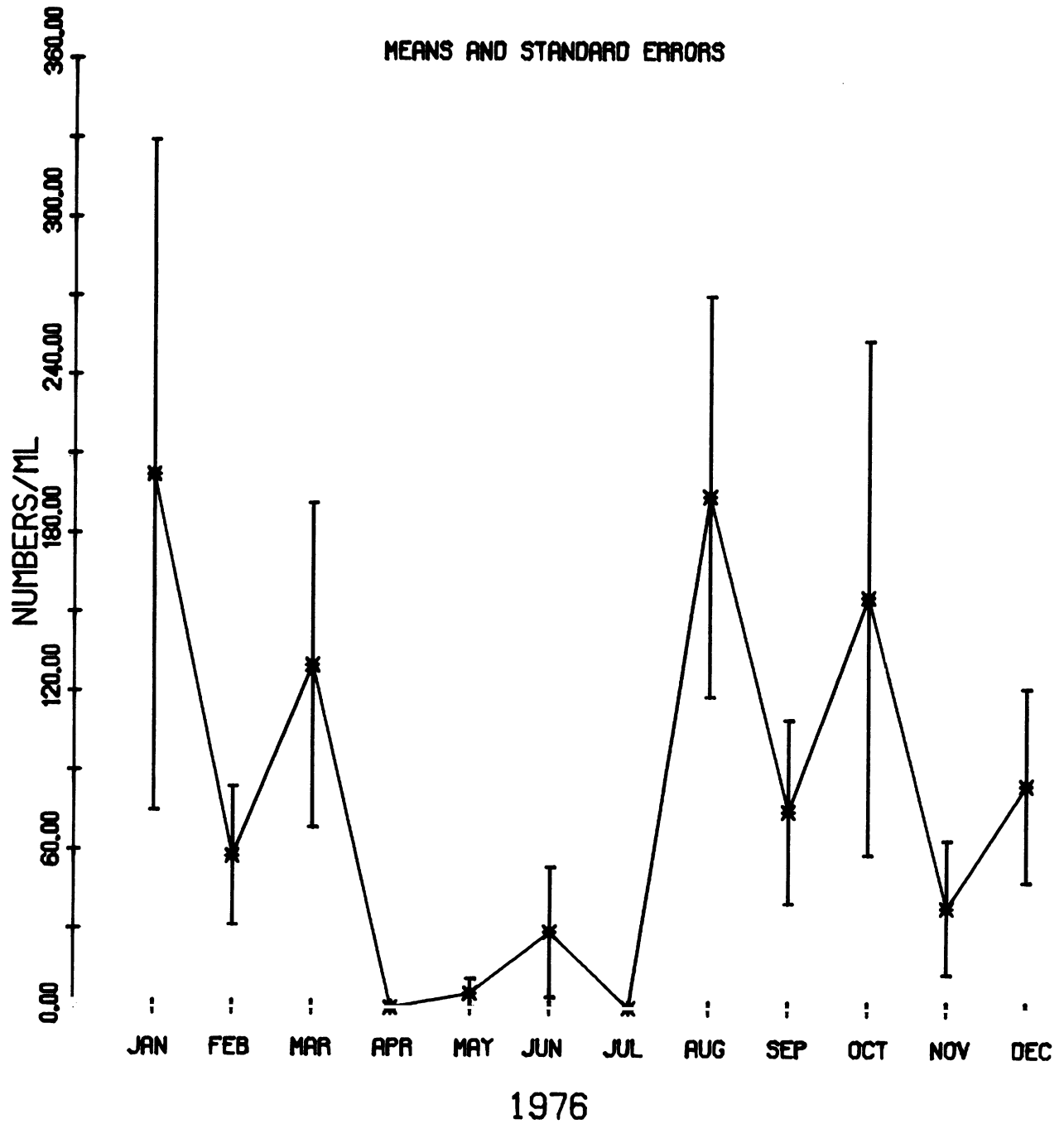


FIG. 13. Variation of Gomphosphaeria lacustris numbers during 1976.

## GOMPHOSPHAERIA LACUSTRUS

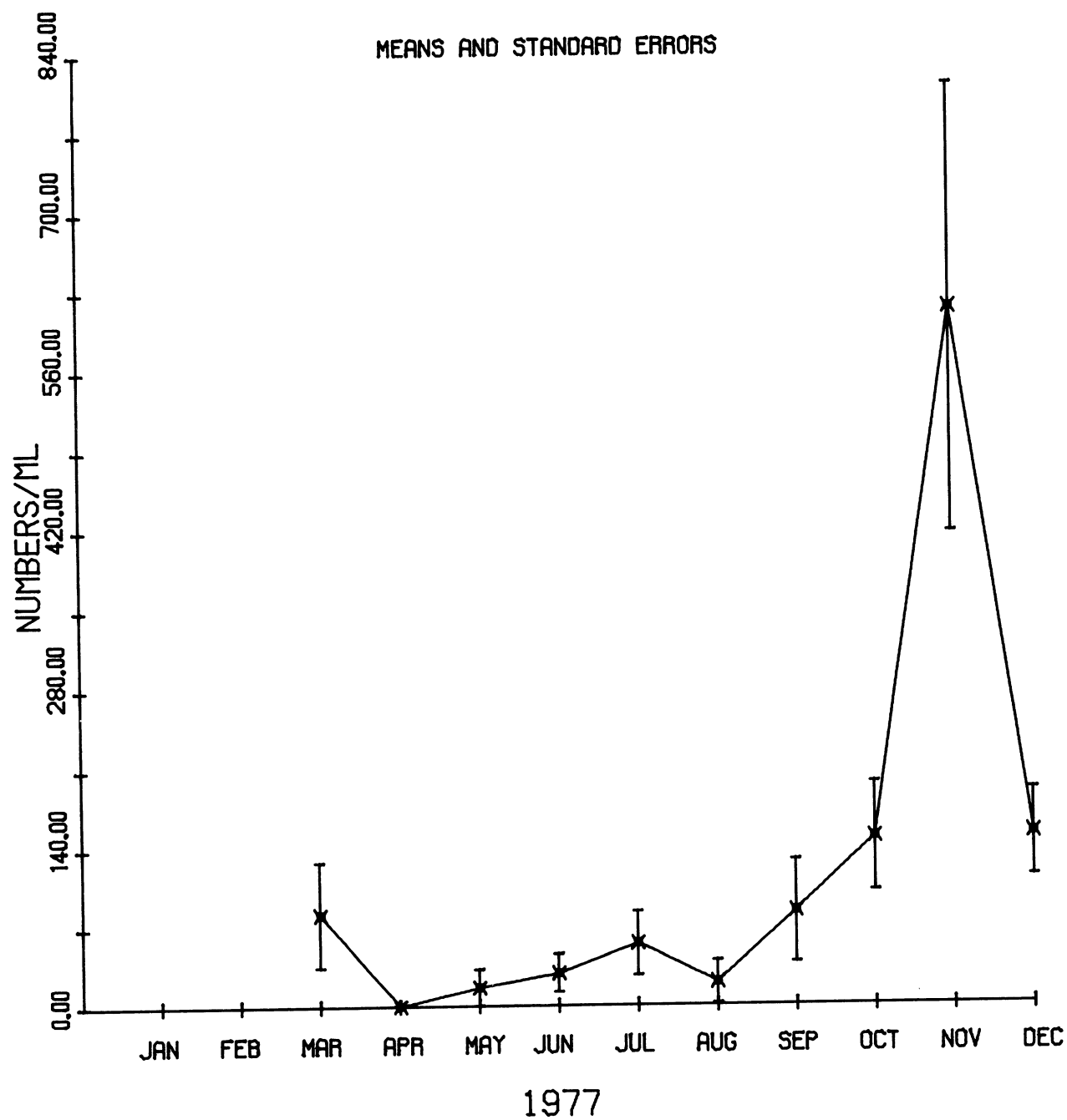


FIG. 14. Variation of Gomphosphaeria lacustris numbers during 1977.

Gomphosphaeria aponia and Gomphosphaeria aponia v. delicatula--

The occurrences of these two coccoid, colonial blue-greens in only January and February 1976 can most likely be considered insignificant (Figures 15-16). The large standard deviations associated with the occurrences strengthen the argument that the algae were not widely dispersed, and in fact were probably found in a few colonies.

Agmenellum quadruplicatum--

The taxonomy of this species was changed in our data in 1975 from Merismopedia tenuissima. As a result the dominance of Merismopedia tenuissima in July 1975 and the dominance of Agmenellum quadruplicatum in November 1975 will be treated as the occurrence of one species. In 1977, this population had cell numbers (Figure 17) approximately equal to those in 1975 (not shown), and higher cell numbers than 1976 (not shown). Variations between the years was most likely part of a natural population variation or multi-celled colonial patchiness.

Oscillatoria limnetica--

Although it is incongruous with most other blue-green algae trends, this species bloomed in the late spring and early summer in 1975 and 1976. (Figures 18-19). However, the lack of a major fall bloom appears to be typical for this species (Ayers 1978, Stoermer and Ladewski 1976). The decrease in cell numbers in 1977 (not shown) may in part be explained by a change in taxonomy. This may have resulted from some of the previously identified Oscillatoria limnetica to

## GOMPHOSPHERIA APONINA

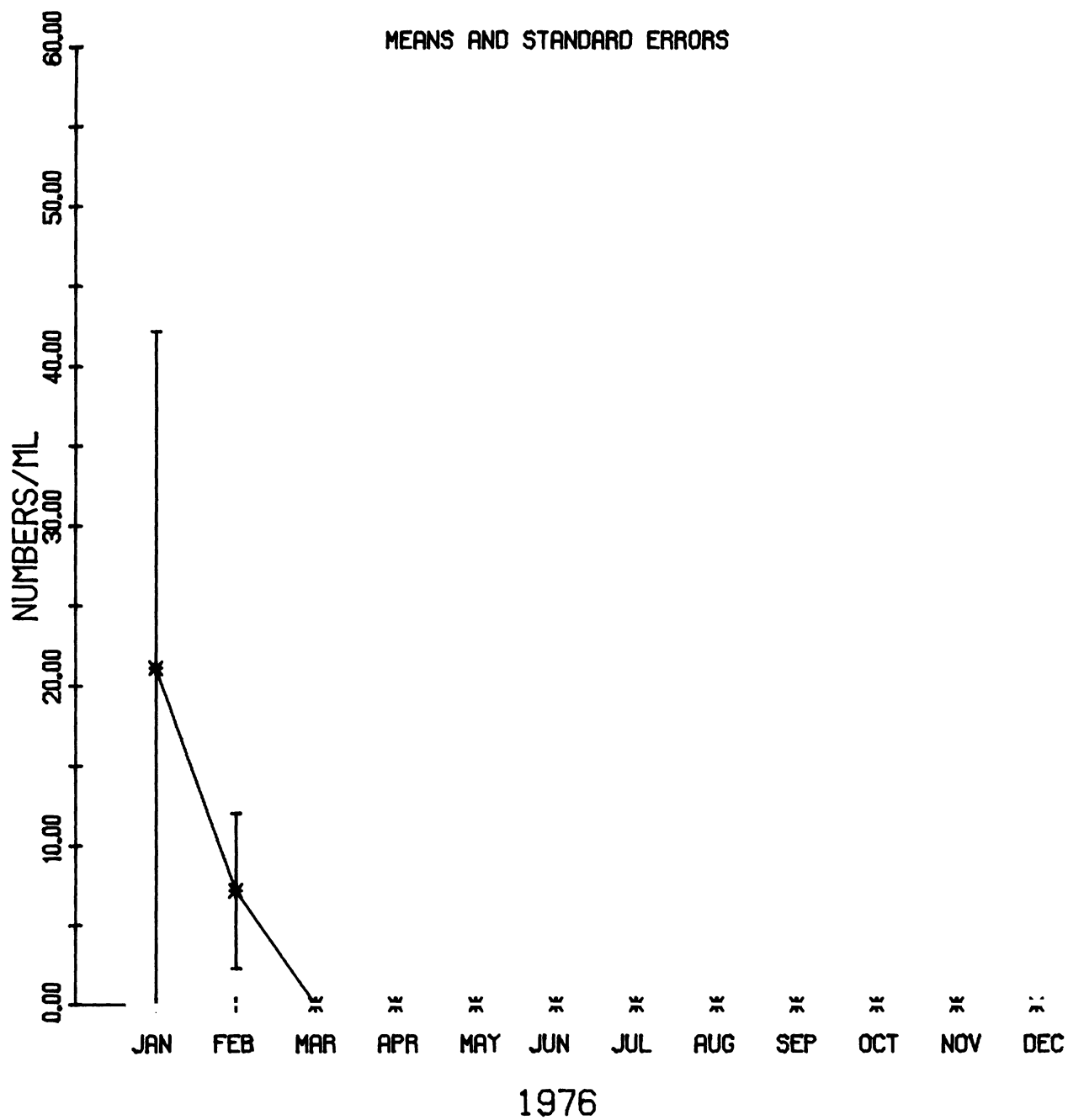


FIG. 15. Variation of Gomphosphaeria aponina numbers during 1976.

# GOMPHOSPHAERIA APONINA V. DELICATULA

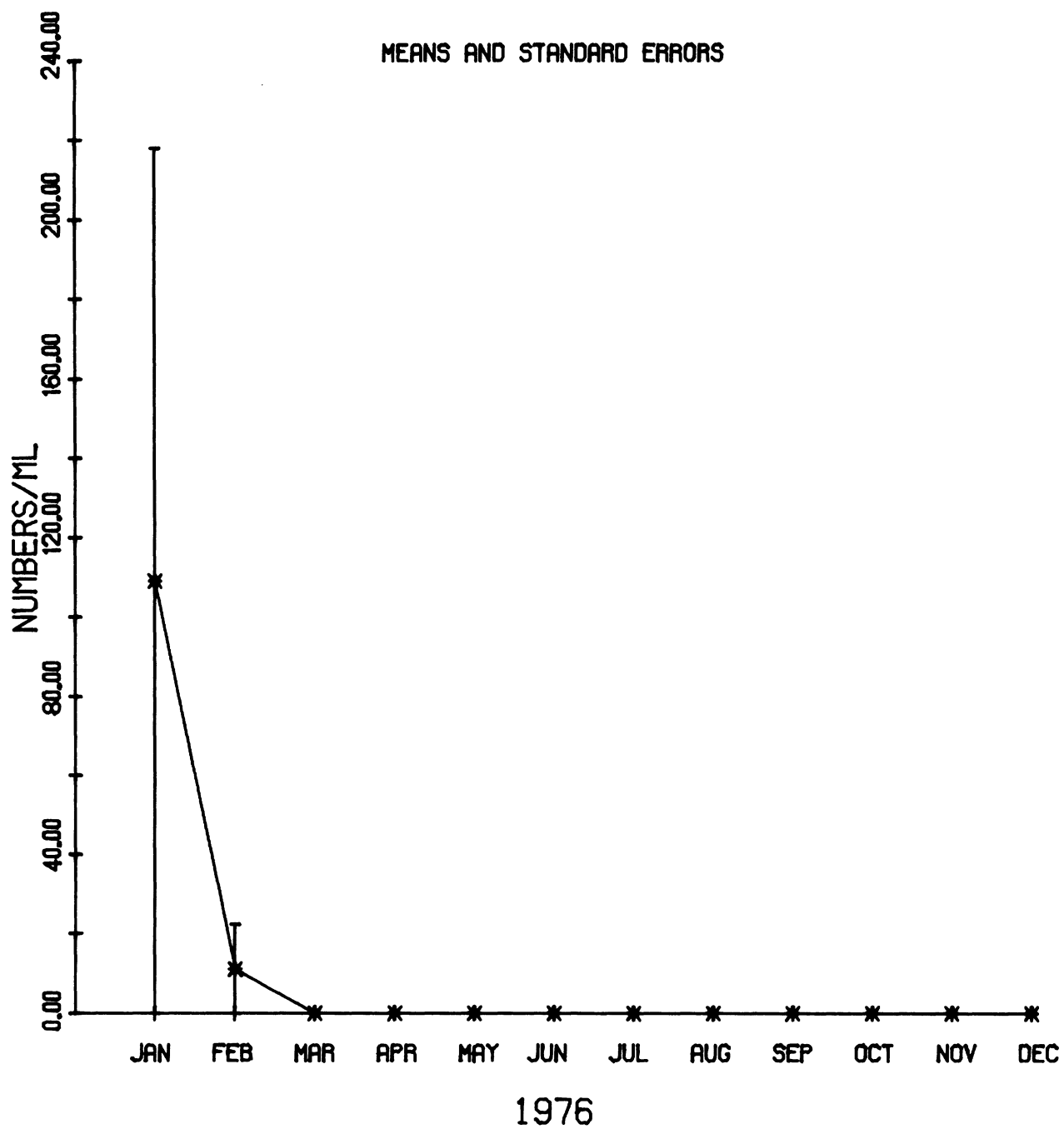


FIG. 16. Variation of Gomphosphaeria aponina v. delicatula numbers during 1976.

# AGMENELLUM QUADRUPLICATUM

MEANS AND STANDARD ERRORS

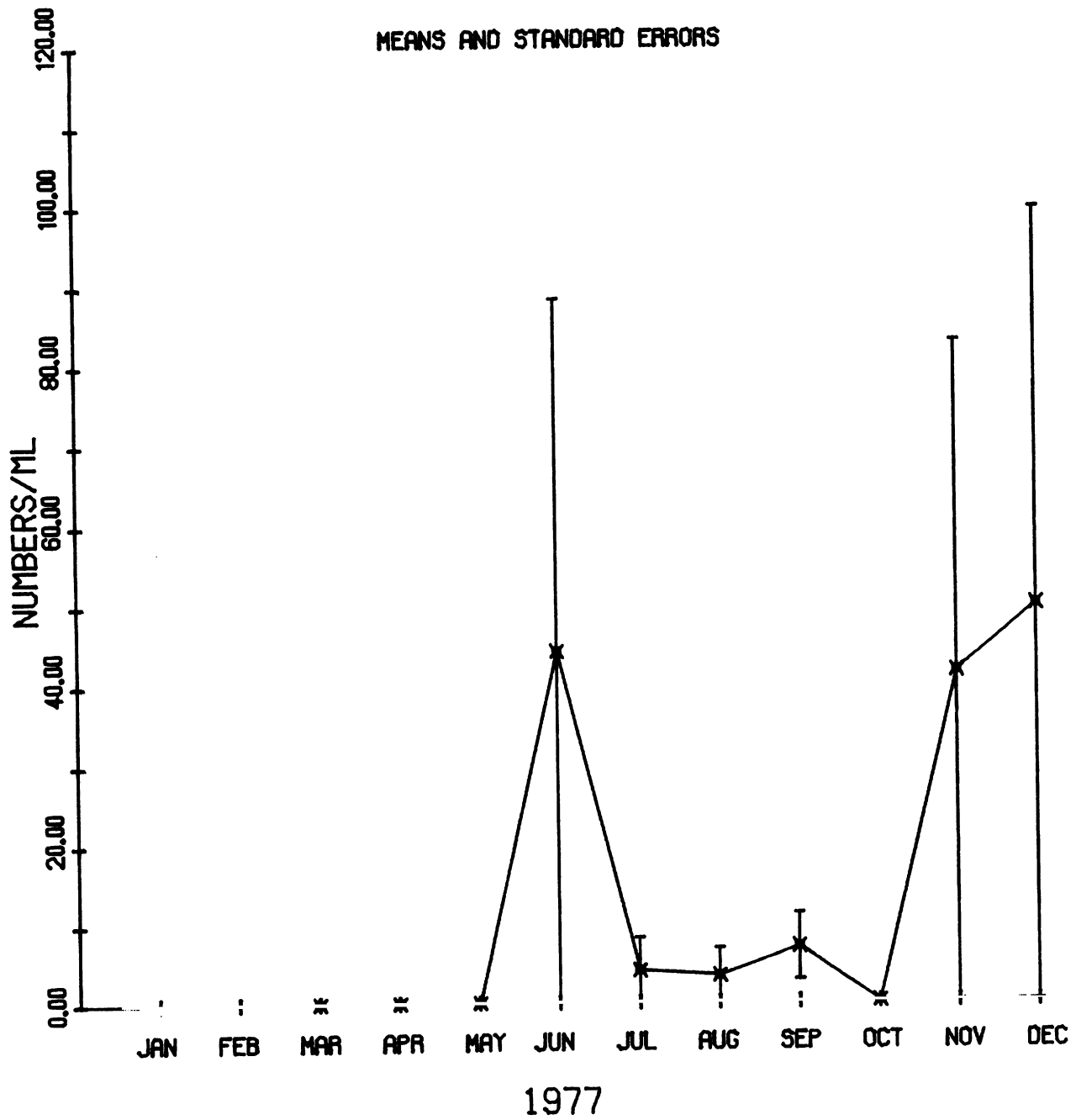


FIG. 17. Variation of Agmenellum quadruplicatum numbers during 1977.

## OSCILLATORIA LIMNETICA

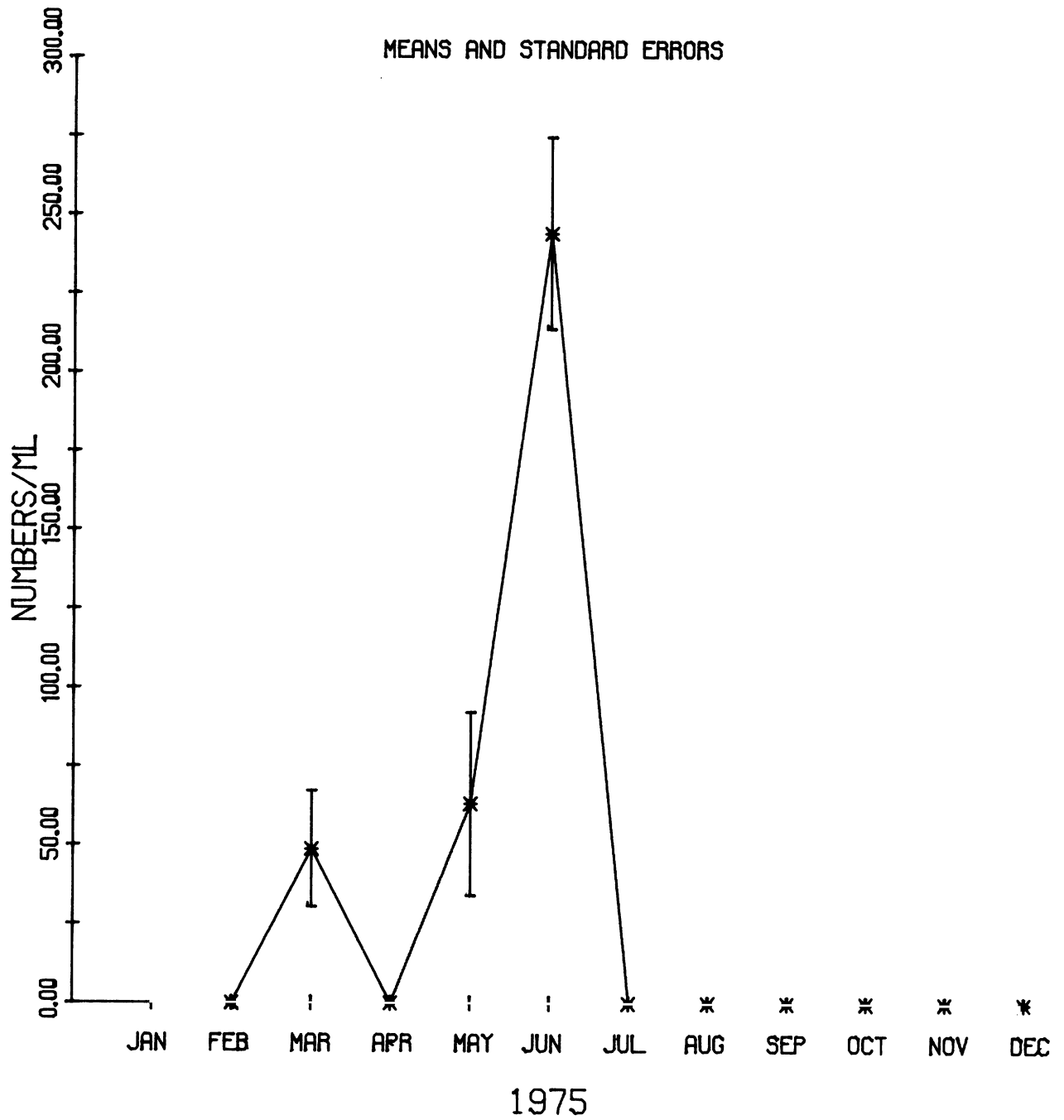


FIG. 18. Variation of Oscillatoria limnetica numbers during 1975.

## OSCILLATORIA LIMNETICA

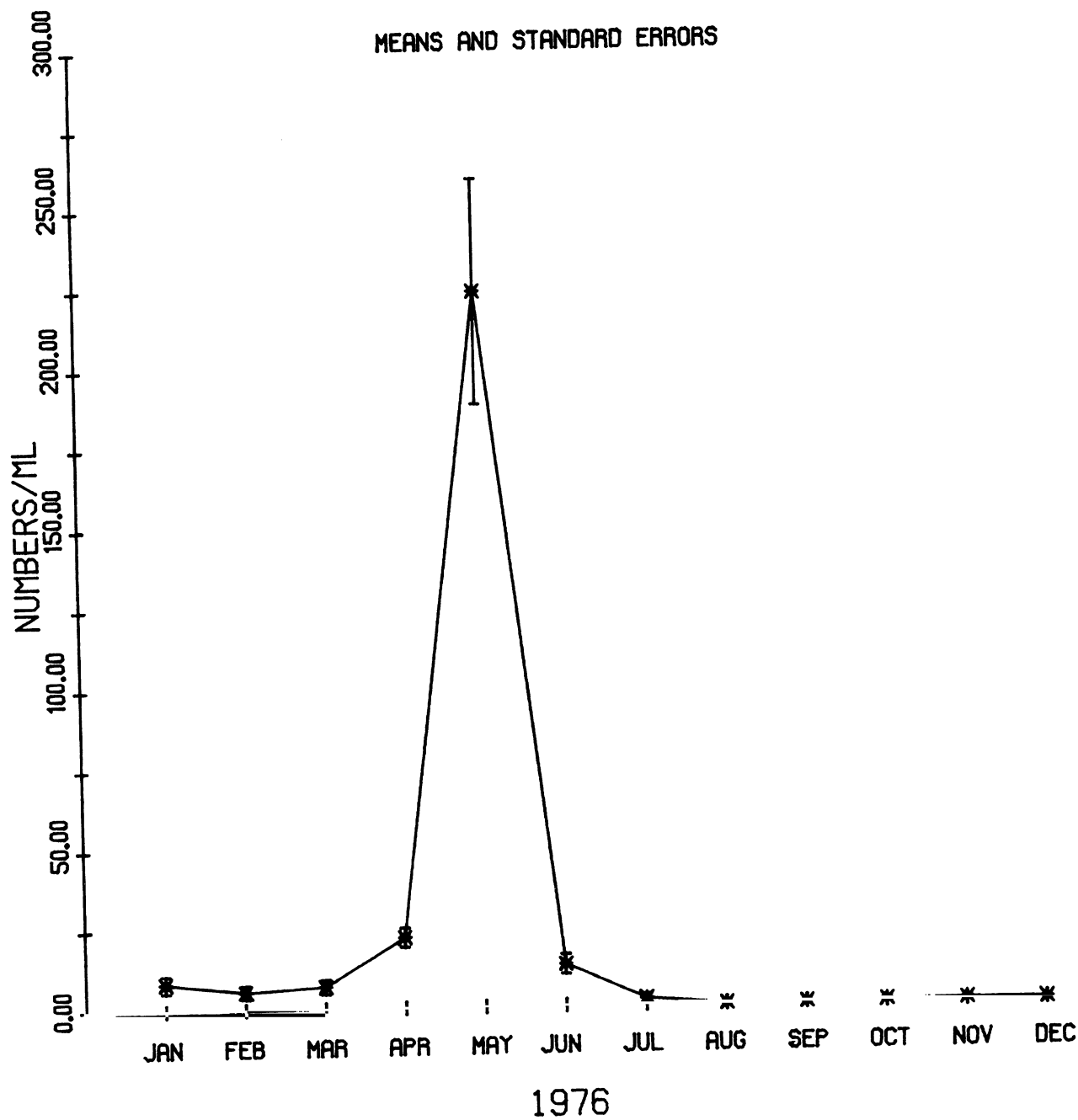


FIG. 19. Variation of Oscillatoria limnetica numbers during 1976.



being classified as Oscillatoria sp. However there was a general decrease in blue-green filaments in 1977.

Chromulina parvula--

The abundance of this Chrysophycean flagellate decreased from 1975 to 1977. This is consistent with lake data (Ayers and Wiley 1979). It was dominant only in 1975, with its major abundance in August (Figure 20). In 1976, the cell numbers remained low with no major blooms (Figure 21). In 1977, this species was never found in numbers greater than 11 cells per mL. At this time, there is little information regarding the habitat preferences of this species, thus no environmental statements may be inferred.

Dinobryon divergens--

There were substantial numbers of this species in October 1975 (Figure 22). However, it only appeared as a dominant for one month in 1976 (Figure 23). During 1977, cell numbers remained low (Figure 24). These occurrences could possibly be accounted for by this species' tendency to form ephemeral blooms (Hutchinson 1967).

Dinobryon bavaricum--

In three years this species only accounted for a substantial part of the population in June 1976 (Figure 25). With this one exception, the population always remained at less than 10 cells per mL. These data do not reflect any trends in environmental change.

# CHROMULINA PARVULA

MEANS AND STANDARD ERRORS

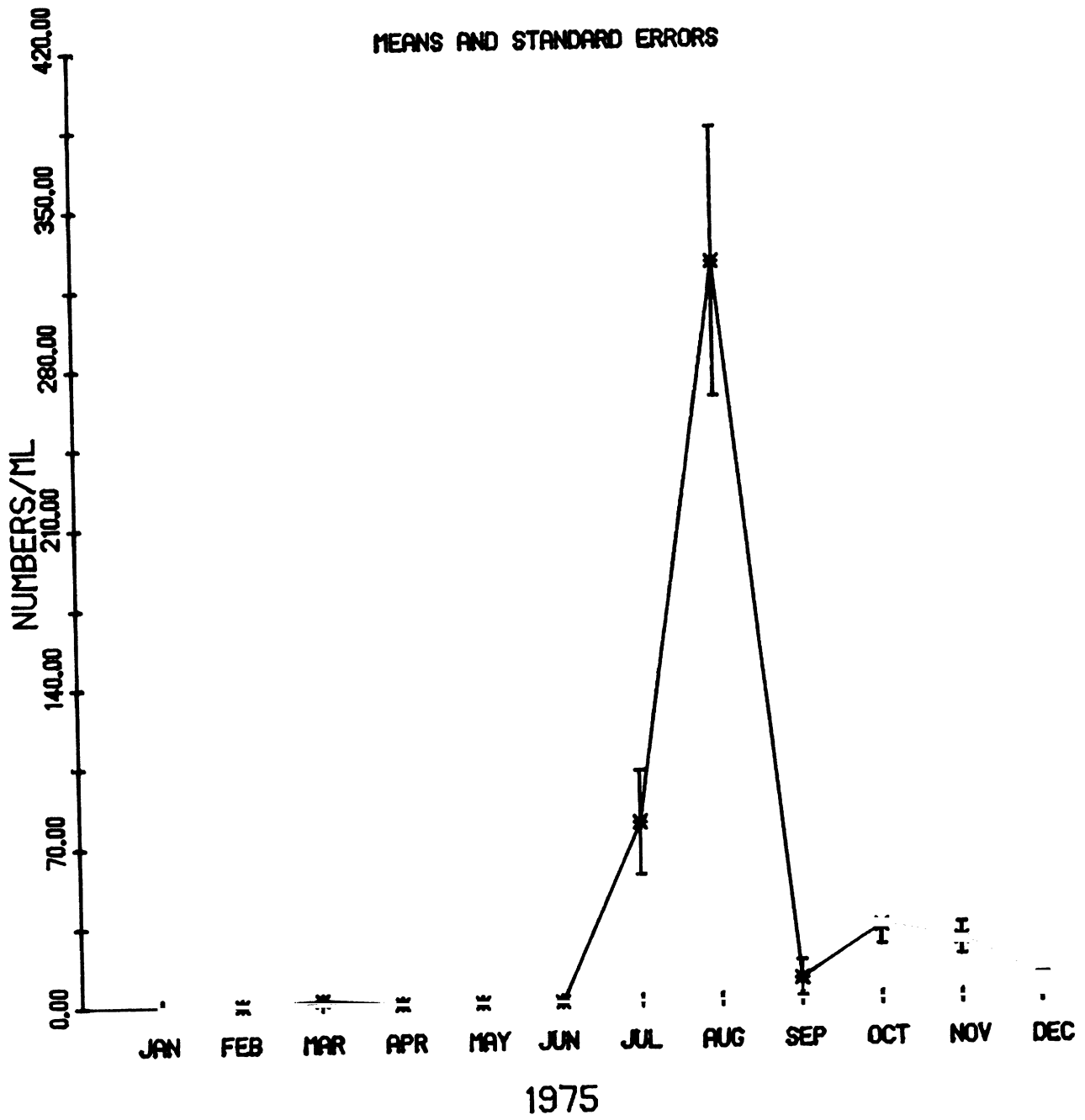


FIG. 20. Variation of Chromulina parvula numbers during 1975.

## CHROMULINA PARVULA

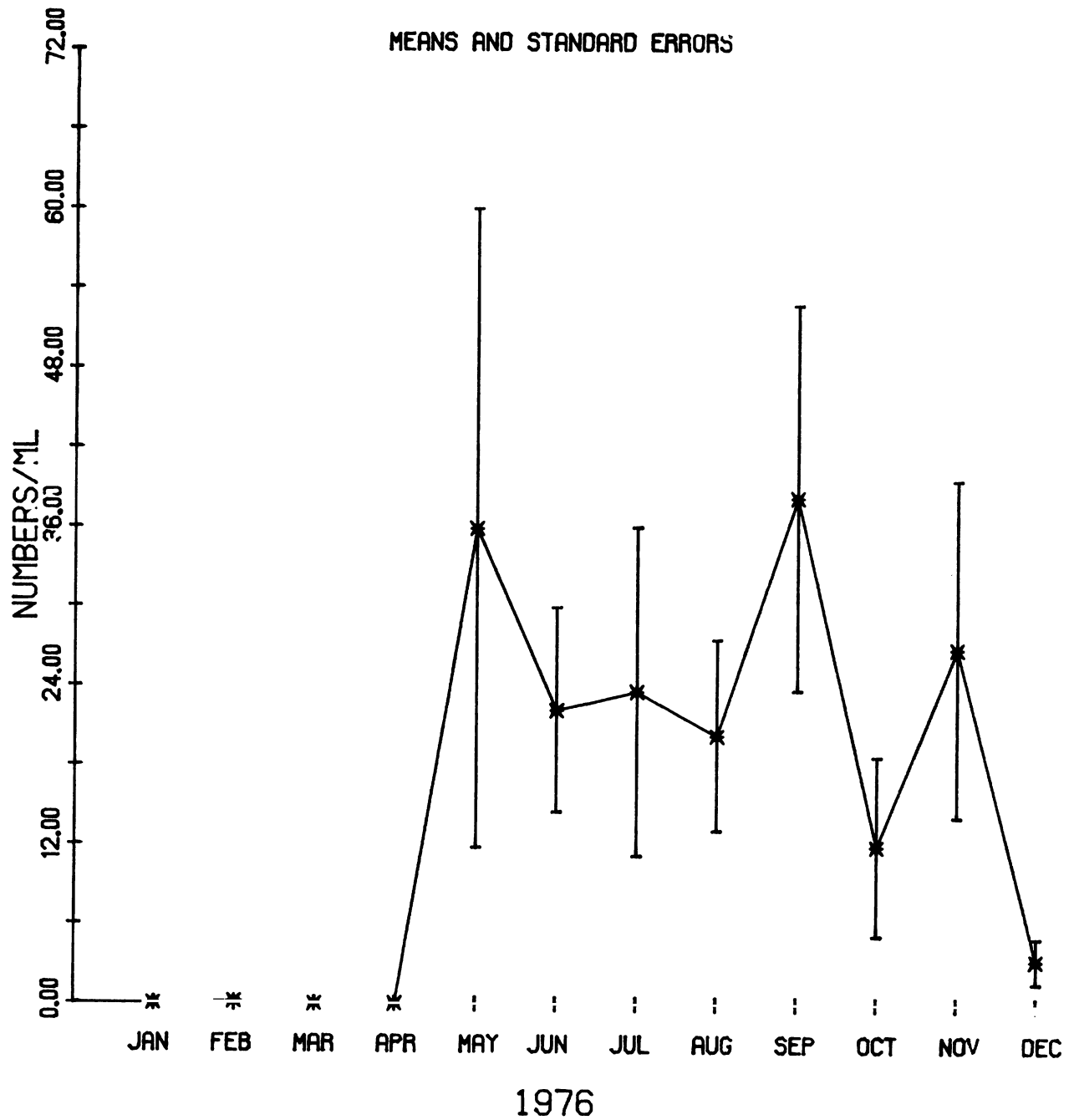


FIG. 21. Variation of Chromulina parvula numbers during 1976.

## DINOBYRON DIVERGENS

MEANS AND STANDARD ERRORS

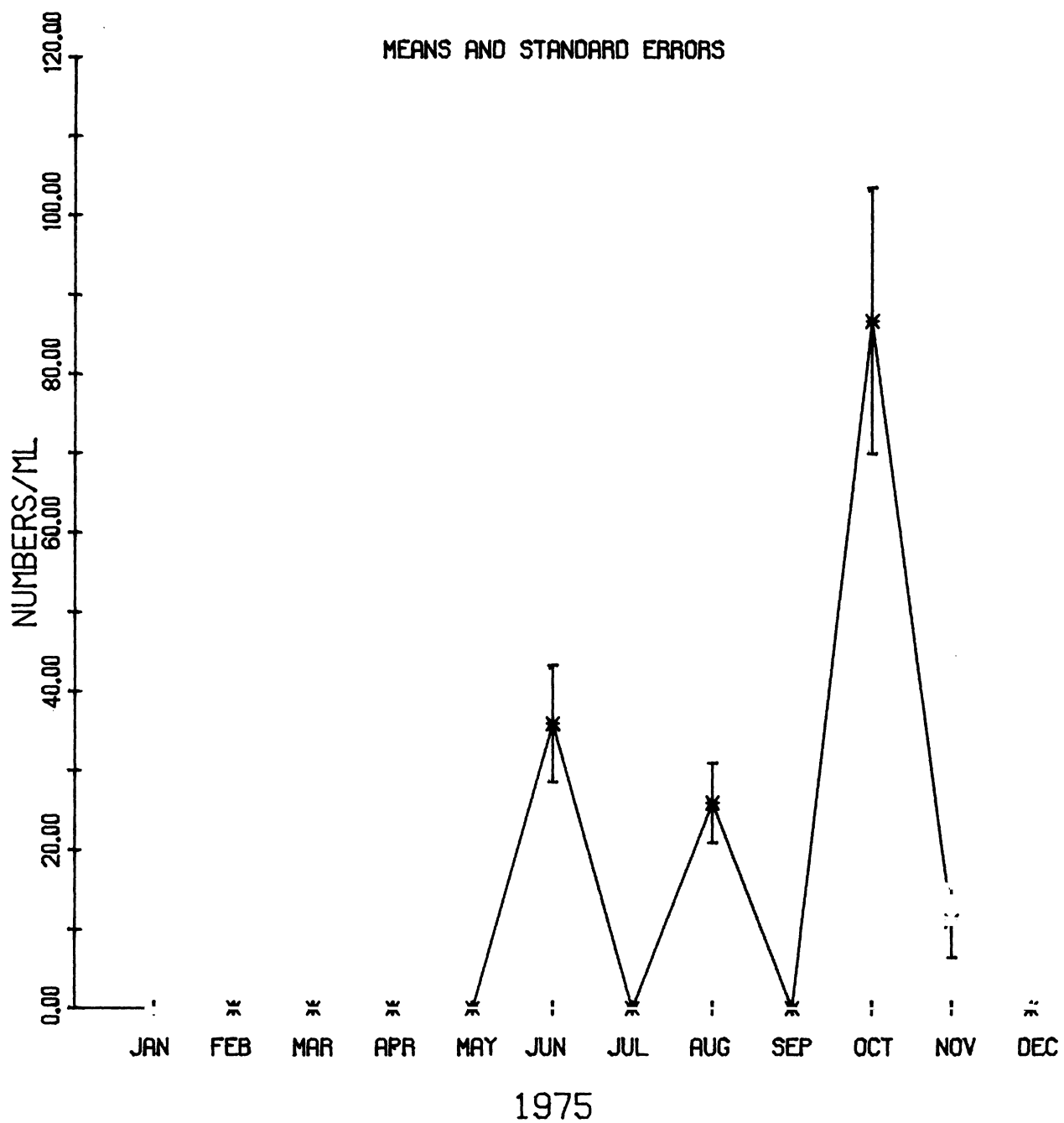


FIG. 22. Variation of *Dinobryon divergens* numbers during 1975.

## DINOBYRON DIVERGENS

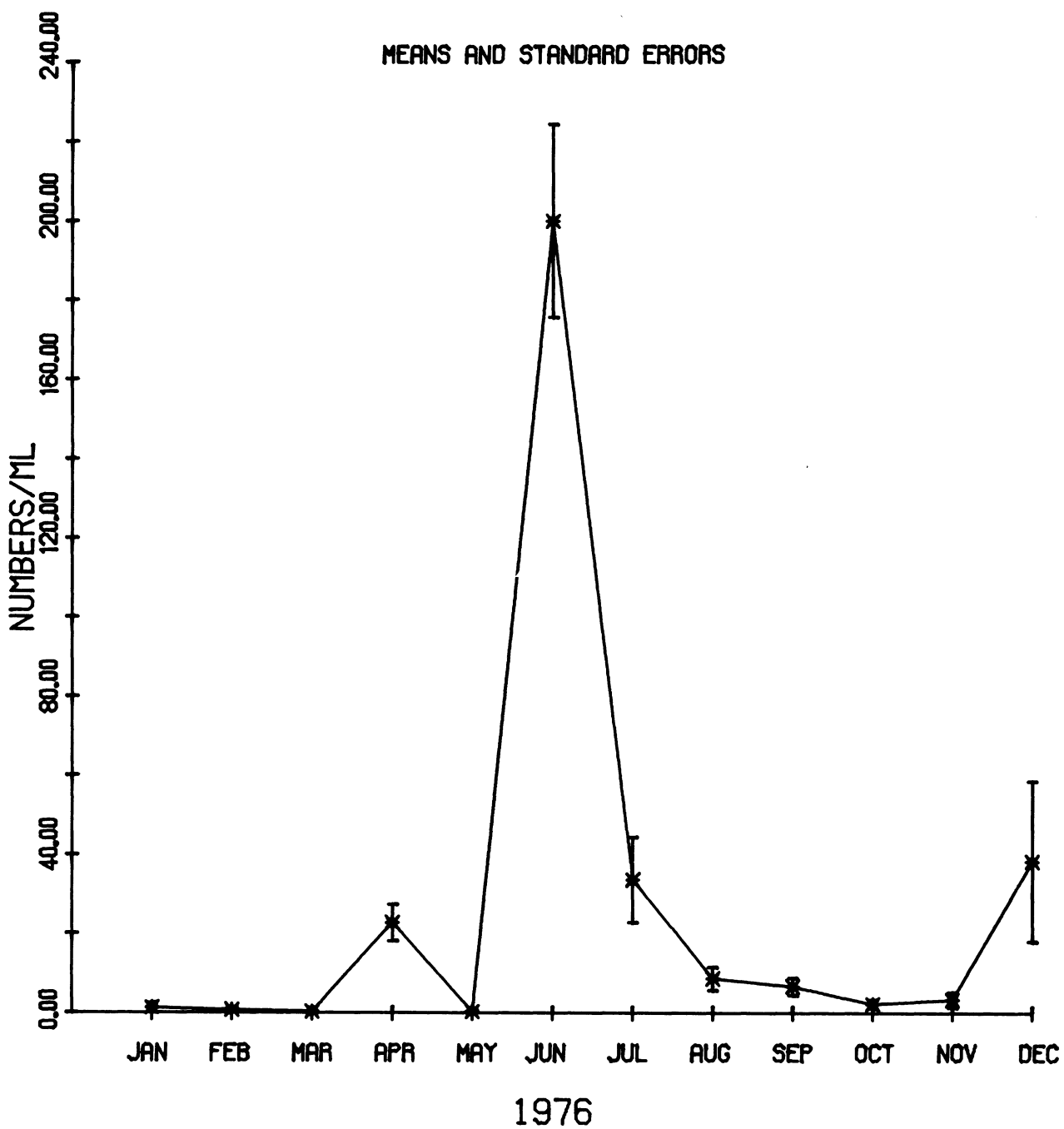


FIG. 23. Variation of Dinobryon divergens numbers during 1976.

## DINOBYRON DIVERGENS

MEANS AND STANDARD ERRORS

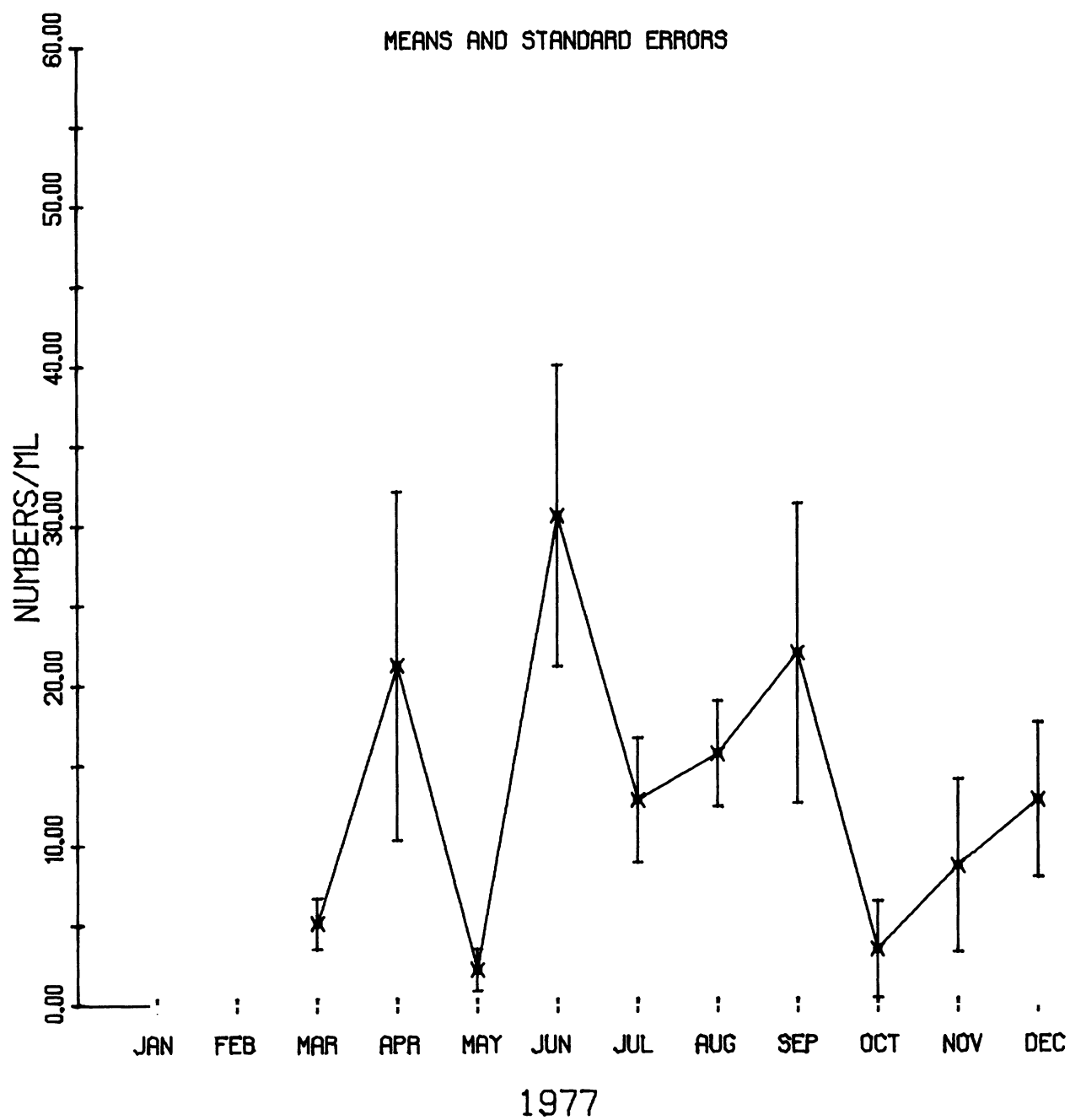


FIG. 24. Variation of Dinobryon divergens numbers during 1977.

# DINOBYRON BAVARICUM

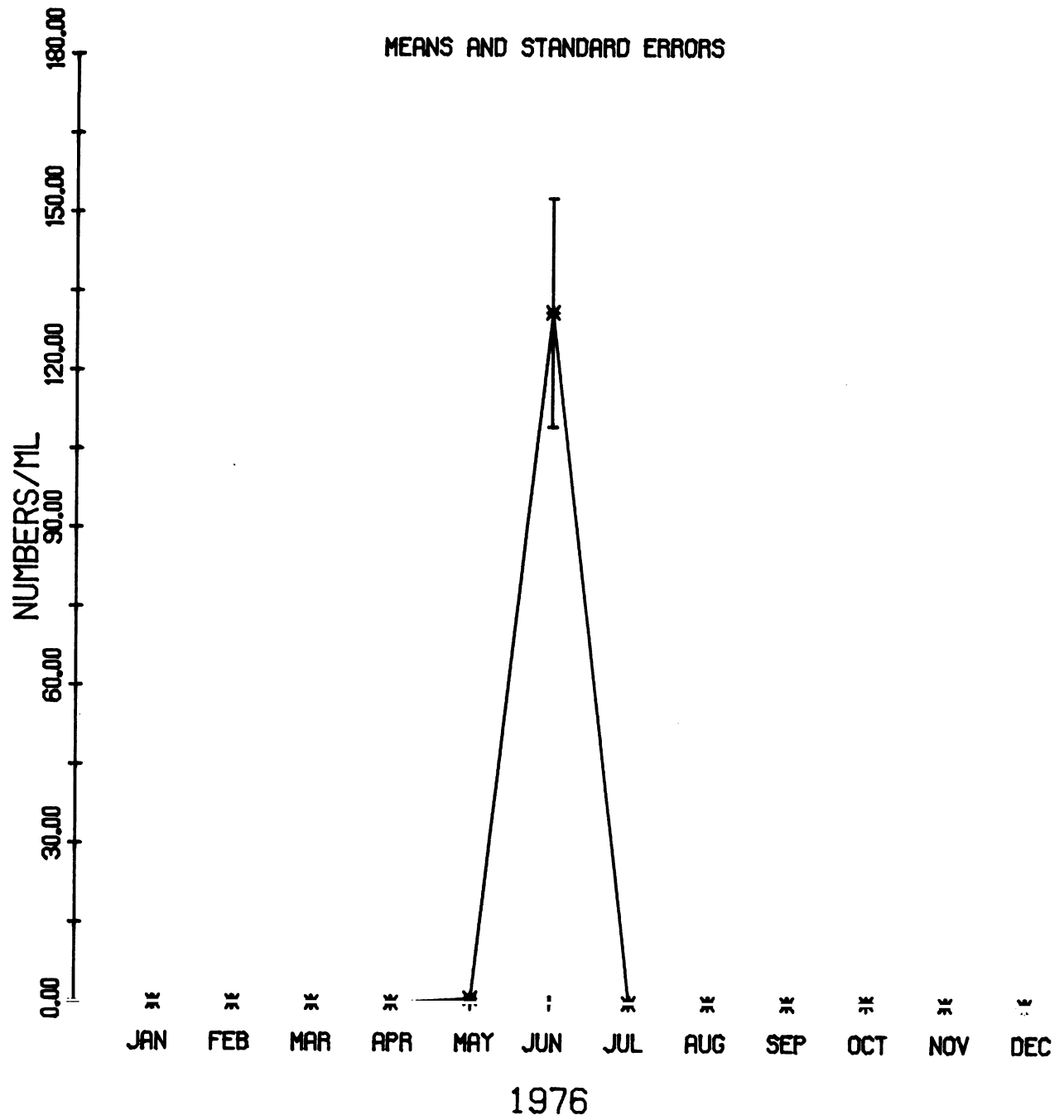


FIG. 25. Variation of Dinobryon bavaricum numbers during 1976.

Gloeocystis planctonica--

In 1975 and 1977, this was a dominant species (Figures 26-28). The abundances were approximately equal for these 2 years. While there was a peak in the population in July of both years, the 1976 maximum abundance occurred in December. This could be due to a thermal effect of the discharge water. In 1977, the total numbers of cells per mL decreased by 67%. This marked decrease was typical of other coccoid green species and of other groups (filamentous blue-greens, centric, and pennate diatoms). Future data must be considered before the significance of these decreases can be commented on.

Sphaerocystis schroeteri--

The only time which this alga appeared as a dominant species in the population was November 1975 (Figure 29). At that time, there was a large standard deviation, indicating that the cells were most likely contained in a few multi-celled colonies. For this reason, the absence of this species as a dominant in 1976 and 1977 is probably not indicative of any physical changes in the intake area.

Dictyosphaerium pulchellum--

July 1975 was the only month in which this species appeared as a dominant (Figure 30). While it is common to have this alga appear as a minor component of the phytoplankton in the Great Lakes, it is not frequently dominant (Stoermer and Ladewski 1976). However, in 1971 Stoermer and Ladewski (1976)



## GLOEOCYSTIS PLANCTONICA

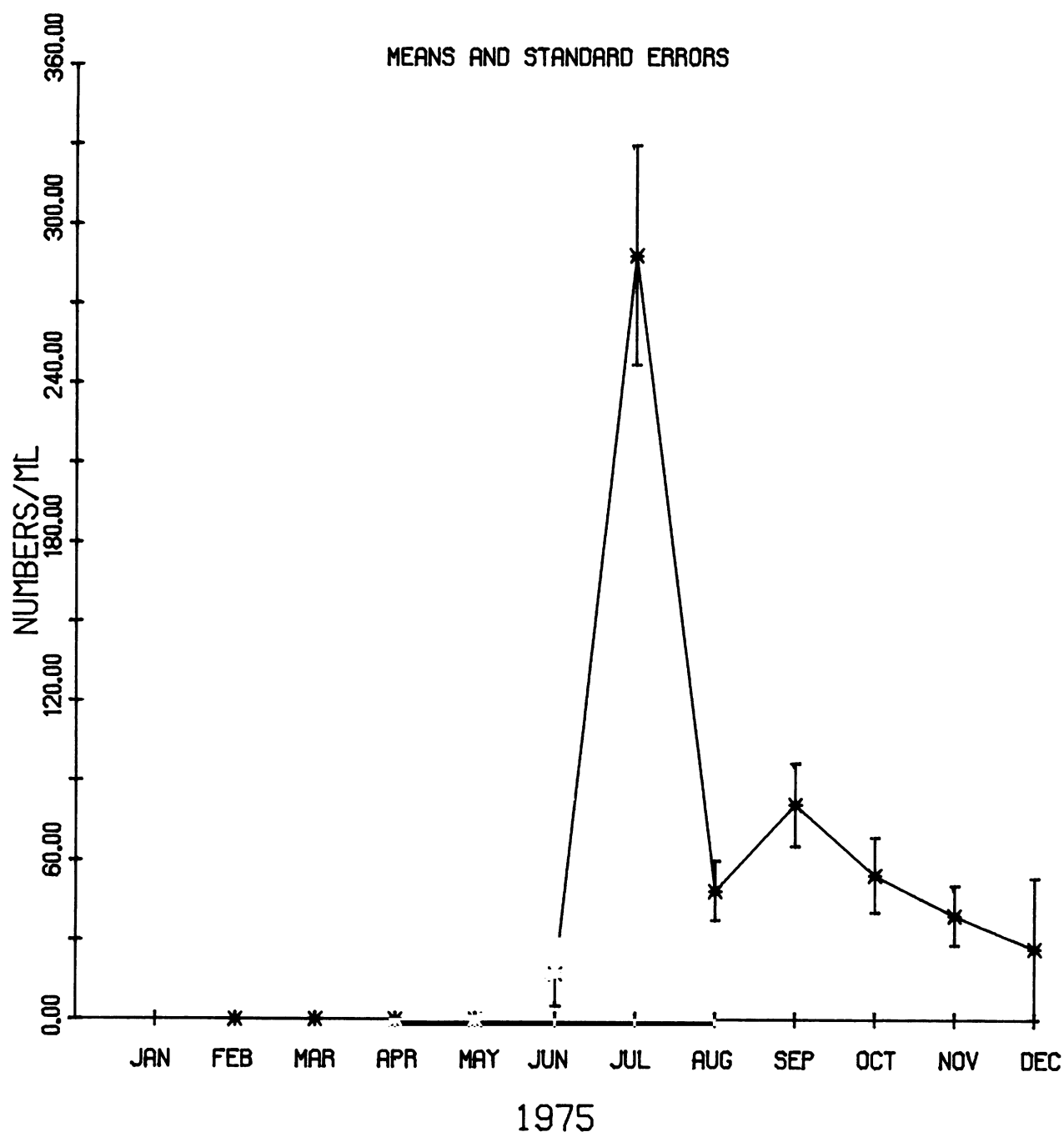


FIG. 26. Variation of Gloeocystis planctonica numbers during 1975.

## GLOEOCYSTIS PLANCTONICA

MEANS AND STANDARD ERRORS

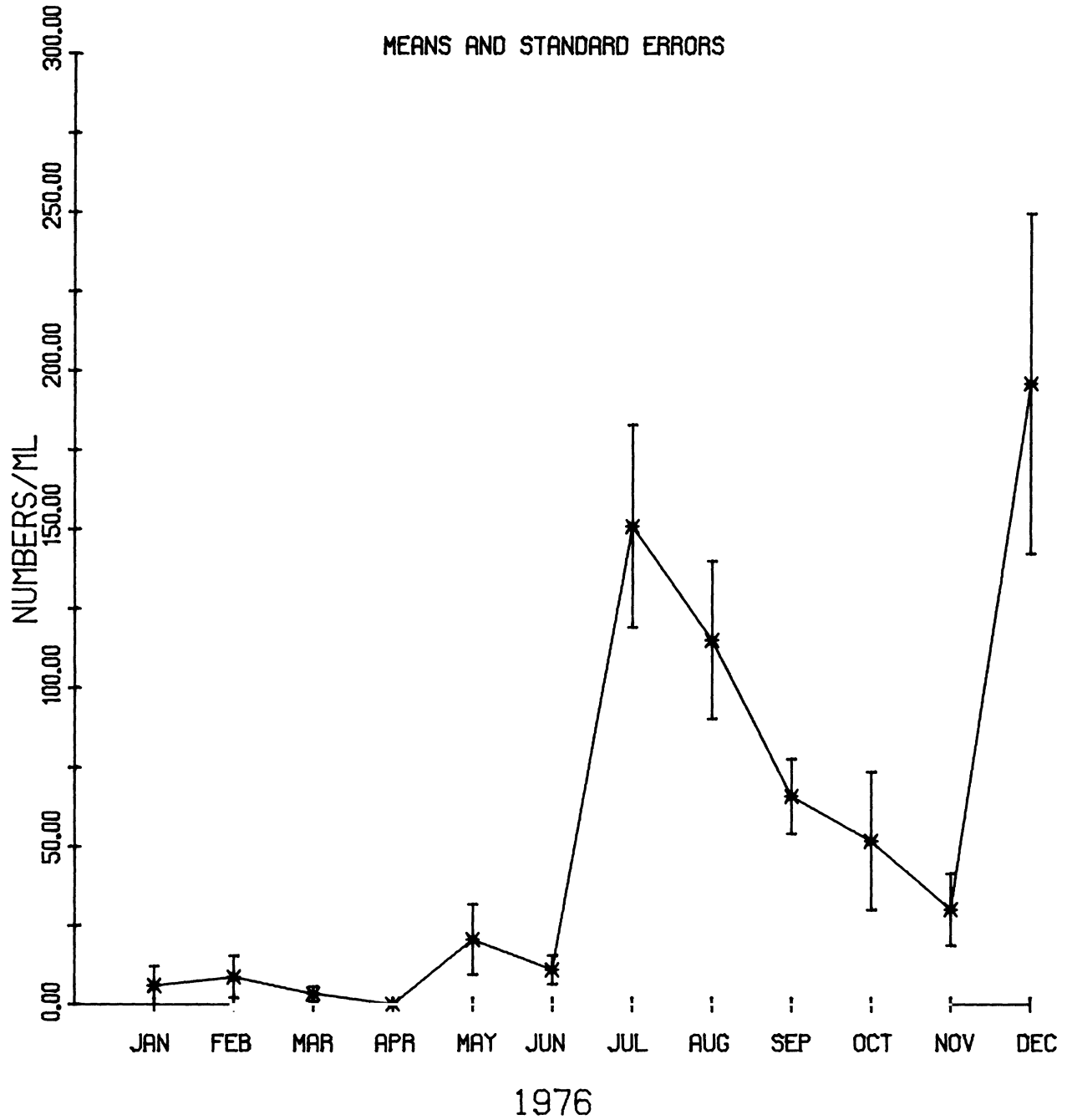


FIG. 27. Variation of Gloeocystis planctonica numbers during 1976.

# GLOEOCYSTIS PLANCTONICA

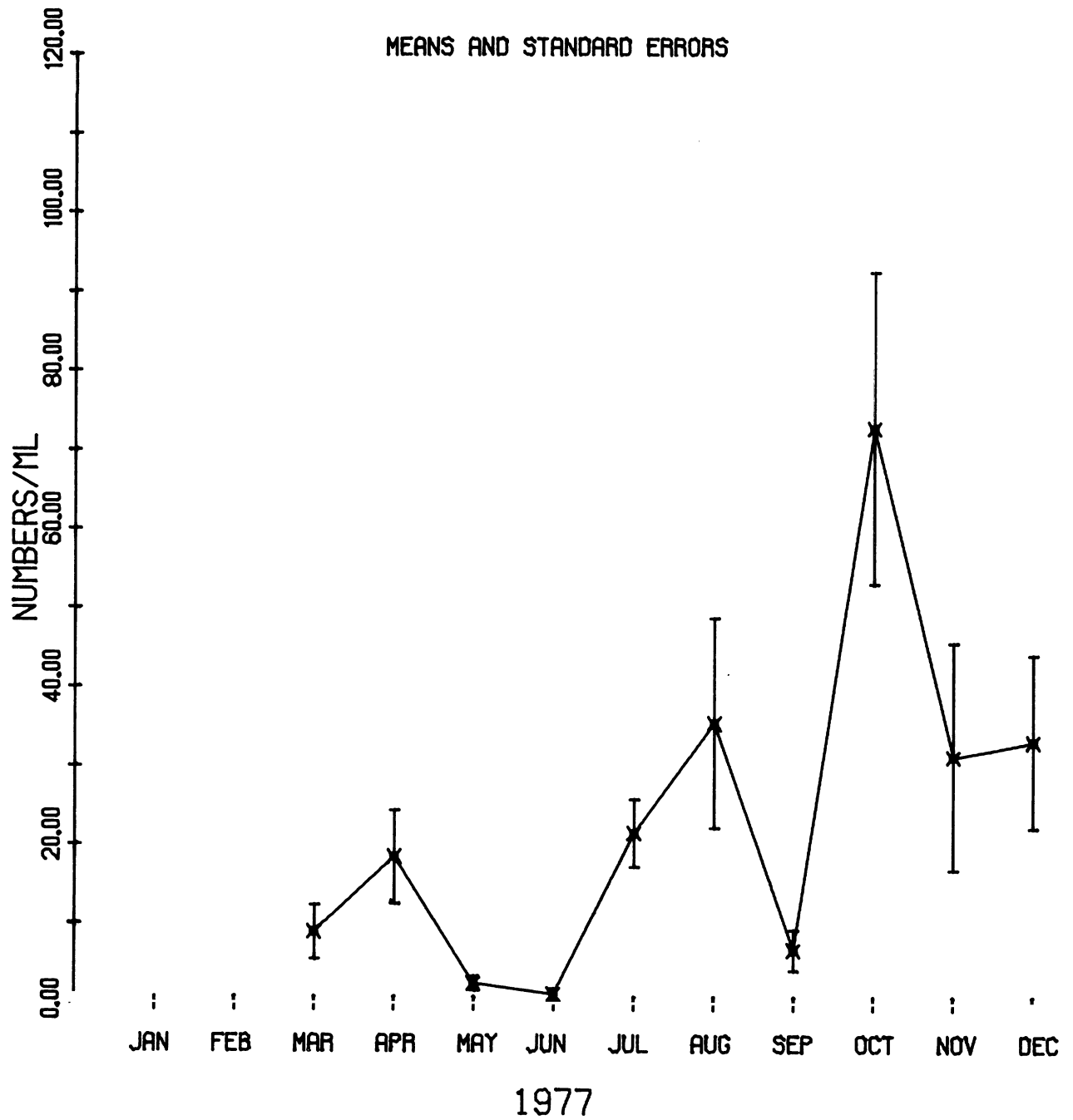


FIG. 28. Variation of Gloeocystis planctonica numbers during 1977.

## SPHAEROCYSTIS SCHROETERI

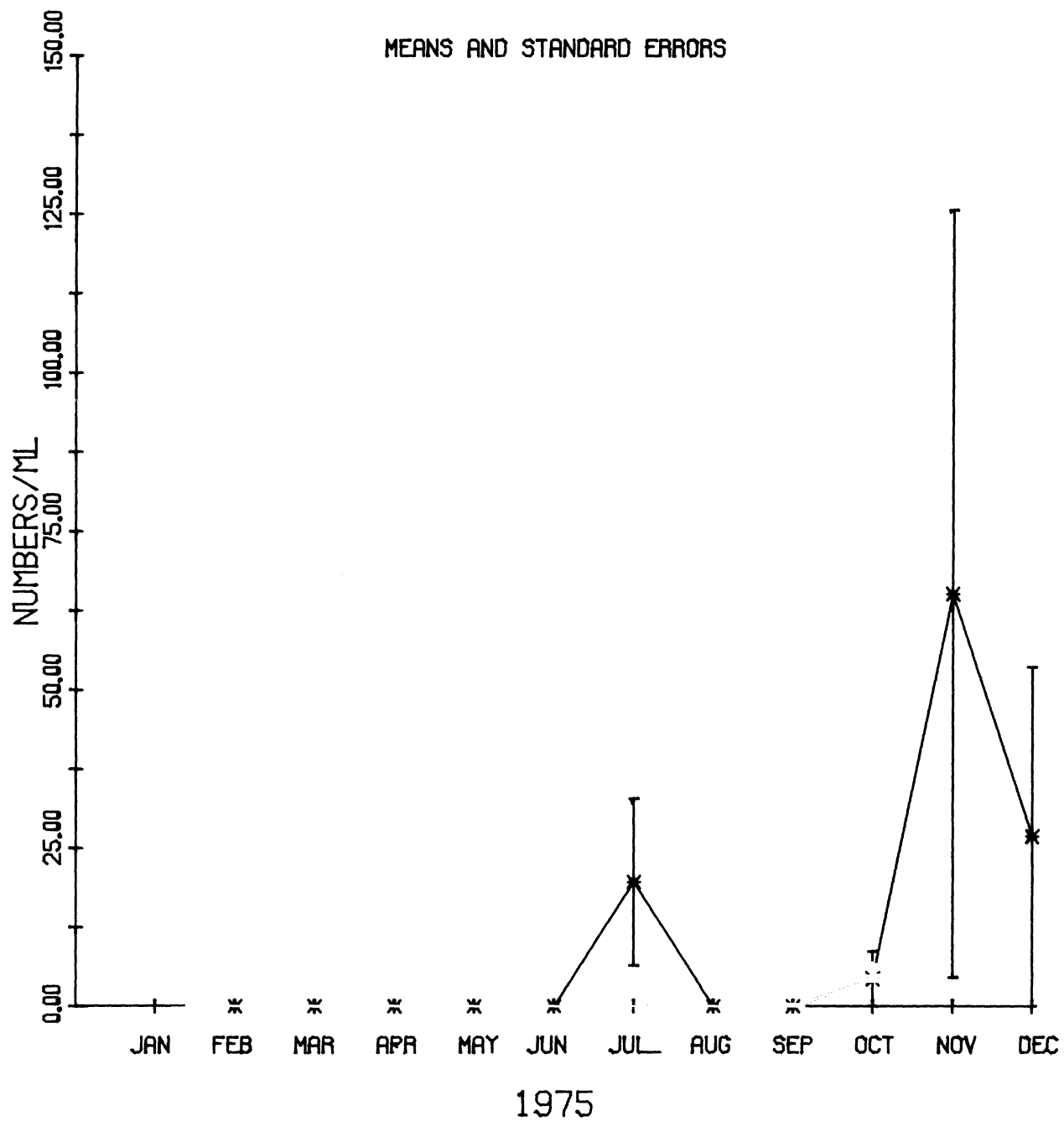


FIG. 29. Variation of Sphaerocystis schroeteri numbers during 1975.

## DICTYOSPHAERIUM PULCHELLUM

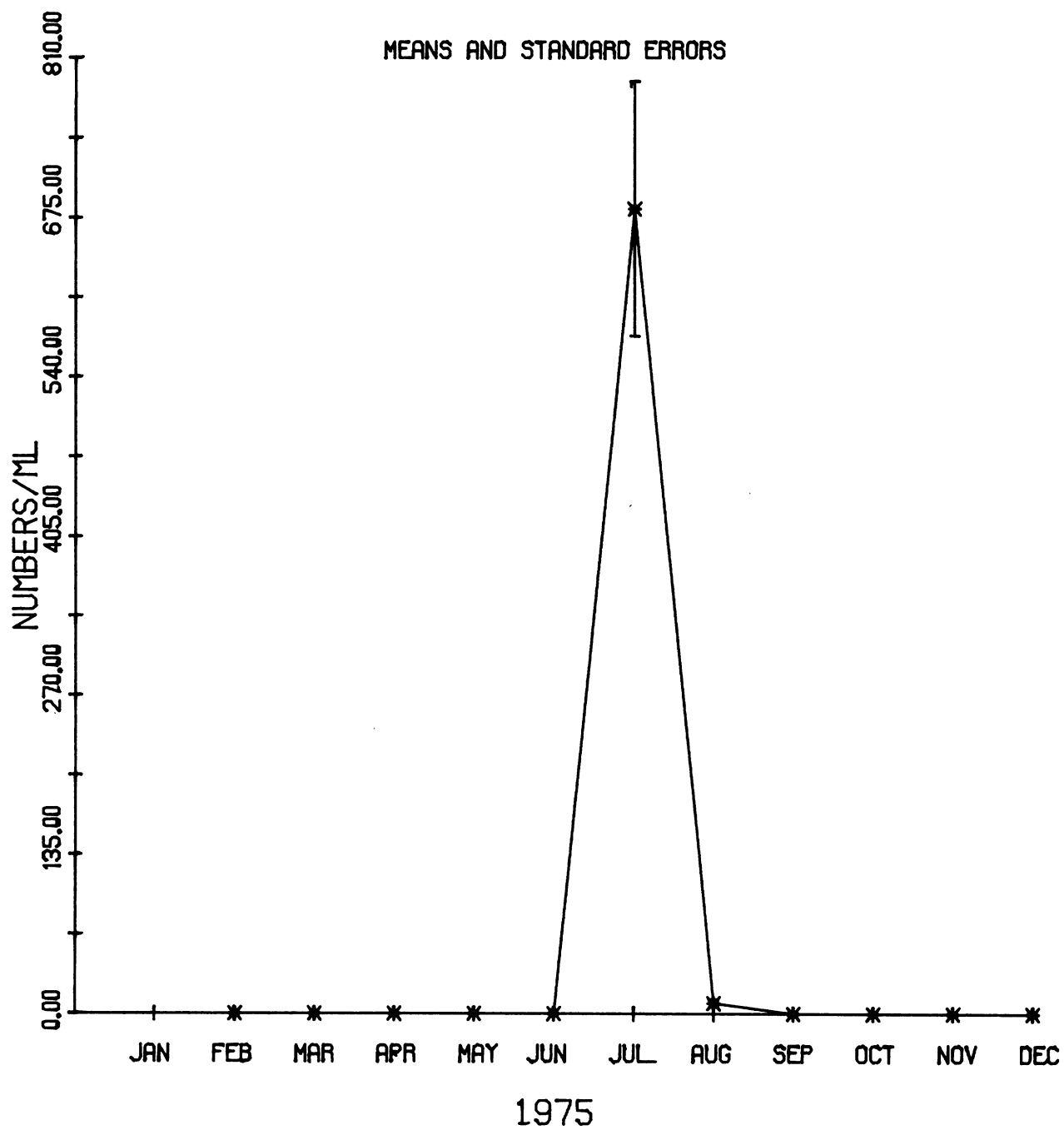


FIG. 30. Variation of Dictyosphaerium pulchellum numbers during 1975.

found it existing in large numbers. Most likely the one time this species appeared in large densities in our data reflected natural population variations.

Crucigenia rectangularis--

This species did not appear in the populations sampled until August 1977 (Figure 31). Stoermer and Ladewski (1976) found it to be limited to water warmer than 16°C. However at this time no direct correlations can be made between the increase in 1977 and the plant. This species also appeared once as a dominant in the control lake stations in November 1970, showing that the abundance in 1977 may not be indicative of a change in the ecological parameters in this area.

Cyclotella comensis--

The abundance of this species has increased since 1975 (Figures 32-34). Its population has increased throughout Lake Michigan (Stoermer and Yang 1969, Ayers and Wiley 1979). Therefore, the increase in the entrainment sample is probably independent of any effect from the Cook Plant. In 1975 and 1976 the only major blooms of this species occurred in late fall and early winter. In 1977, a bloom occurred in July. These data are consistent with control station data from this area (Ayers and Wiley 1979), with the exception of an additional bloom in the fall of 1977. The absence of spring blooms are most likely due to the preference this species has for lower silica concentrations (Hutchinson 1967).

# CRUCIGENIA RECTANGULARIS

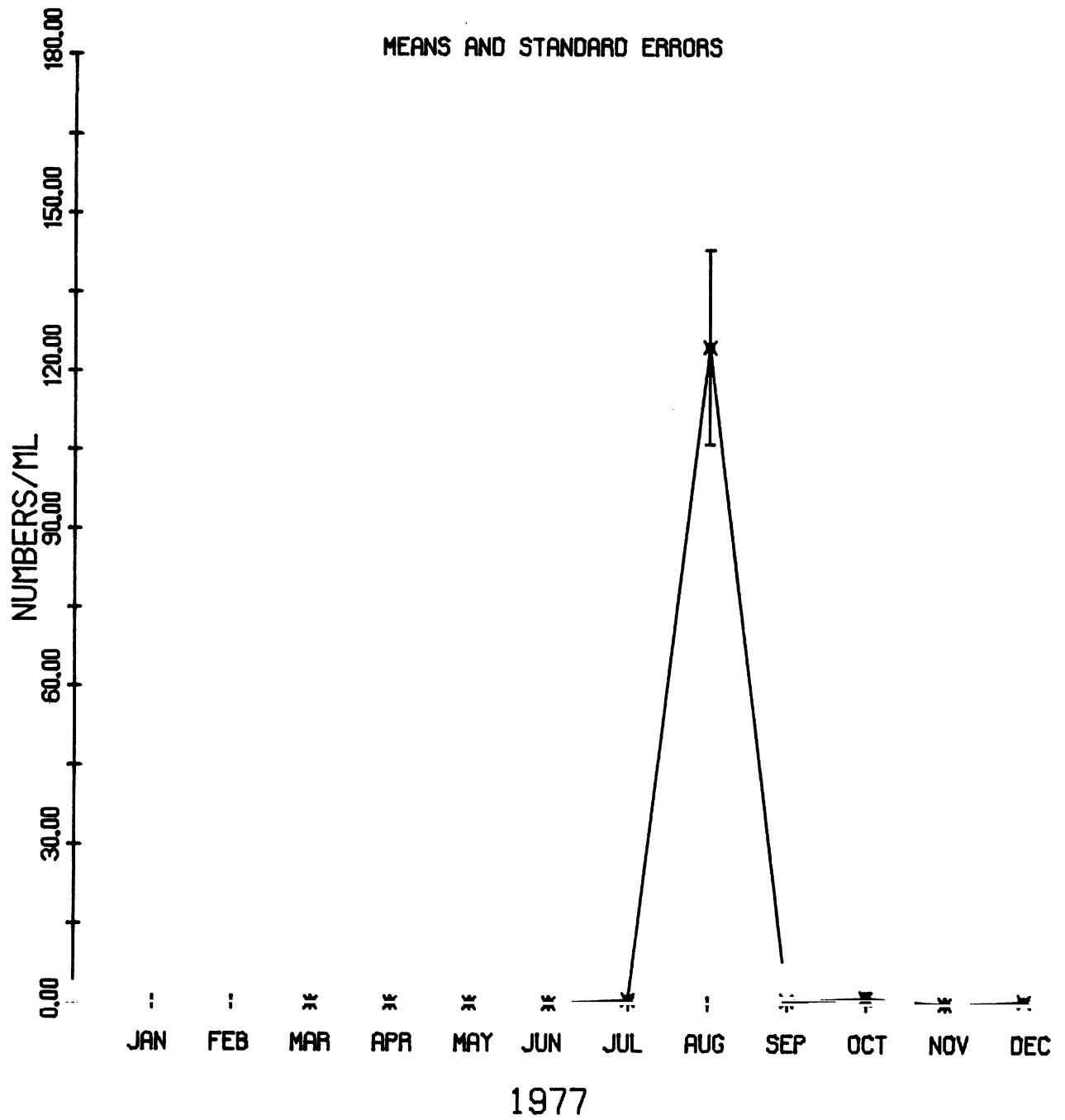


FIG. 31. Variation of Crucigenia rectangularis numbers during 1977.

# CYCLOTELLA COMENSIS

MEANS AND STANDARD ERRORS

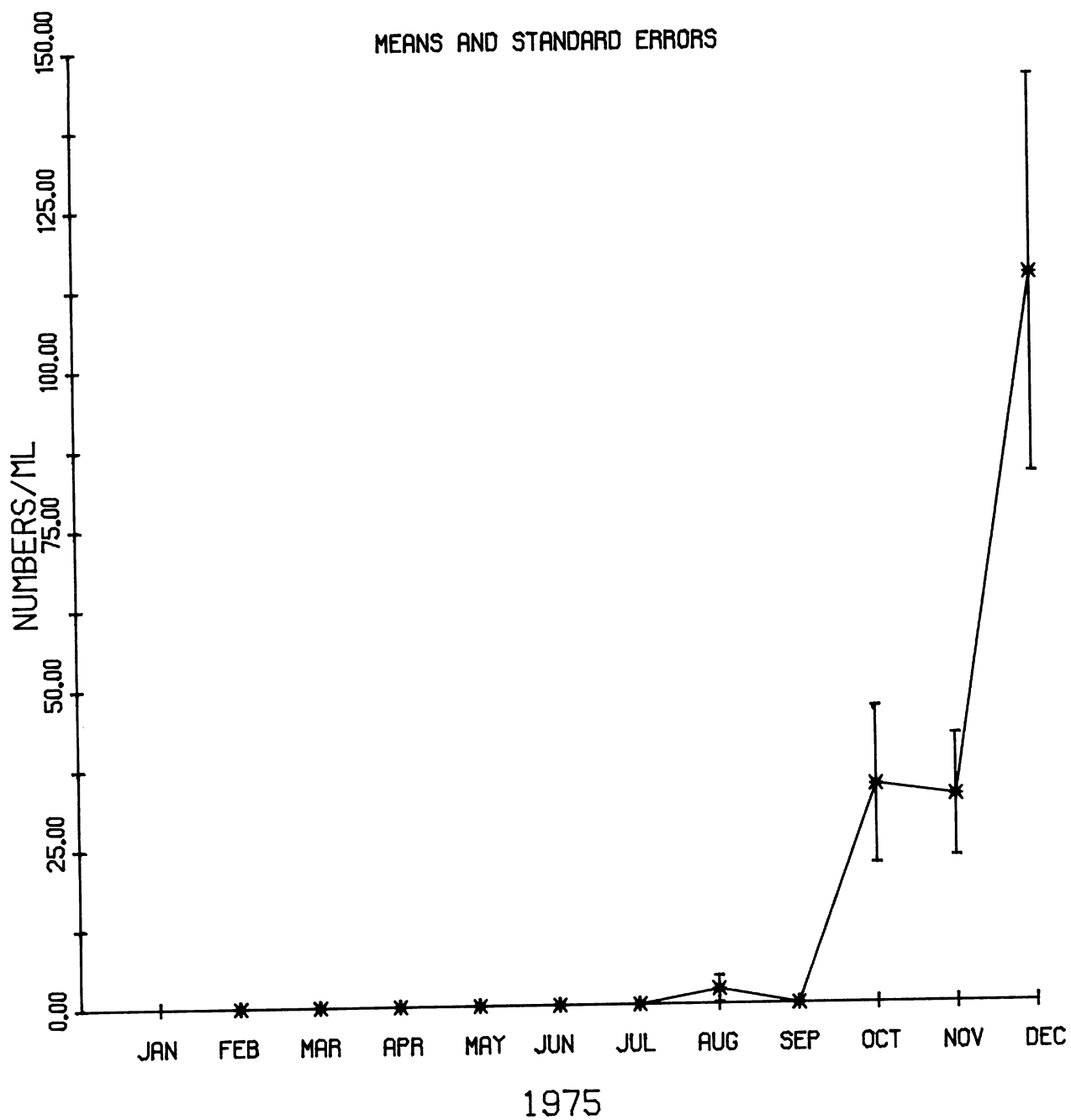


FIG. 32. Variation of Cyclotella comensis numbers during 1975.



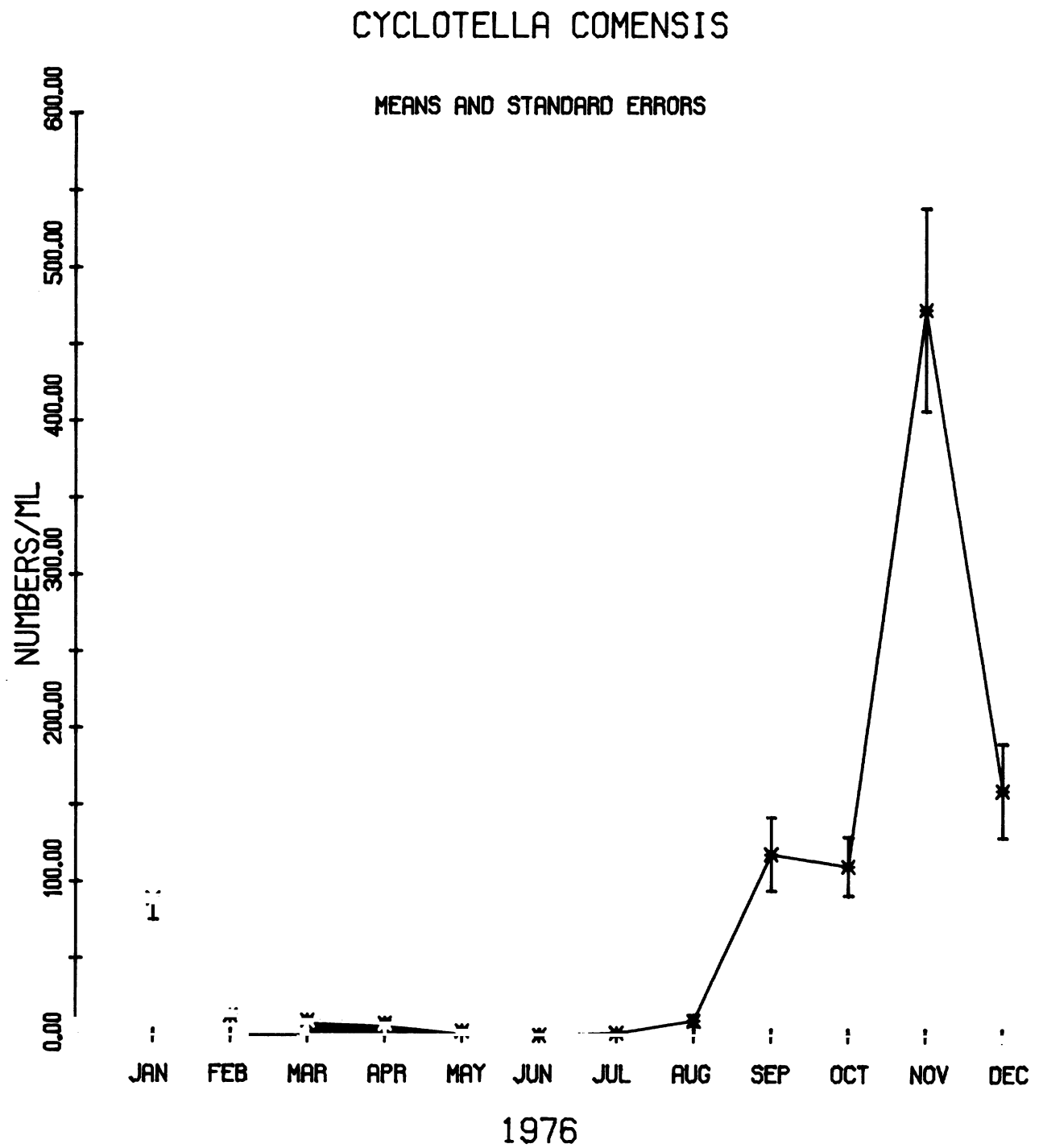


FIG. 33. Variation of Cyclotella comensis numbers during 1976.

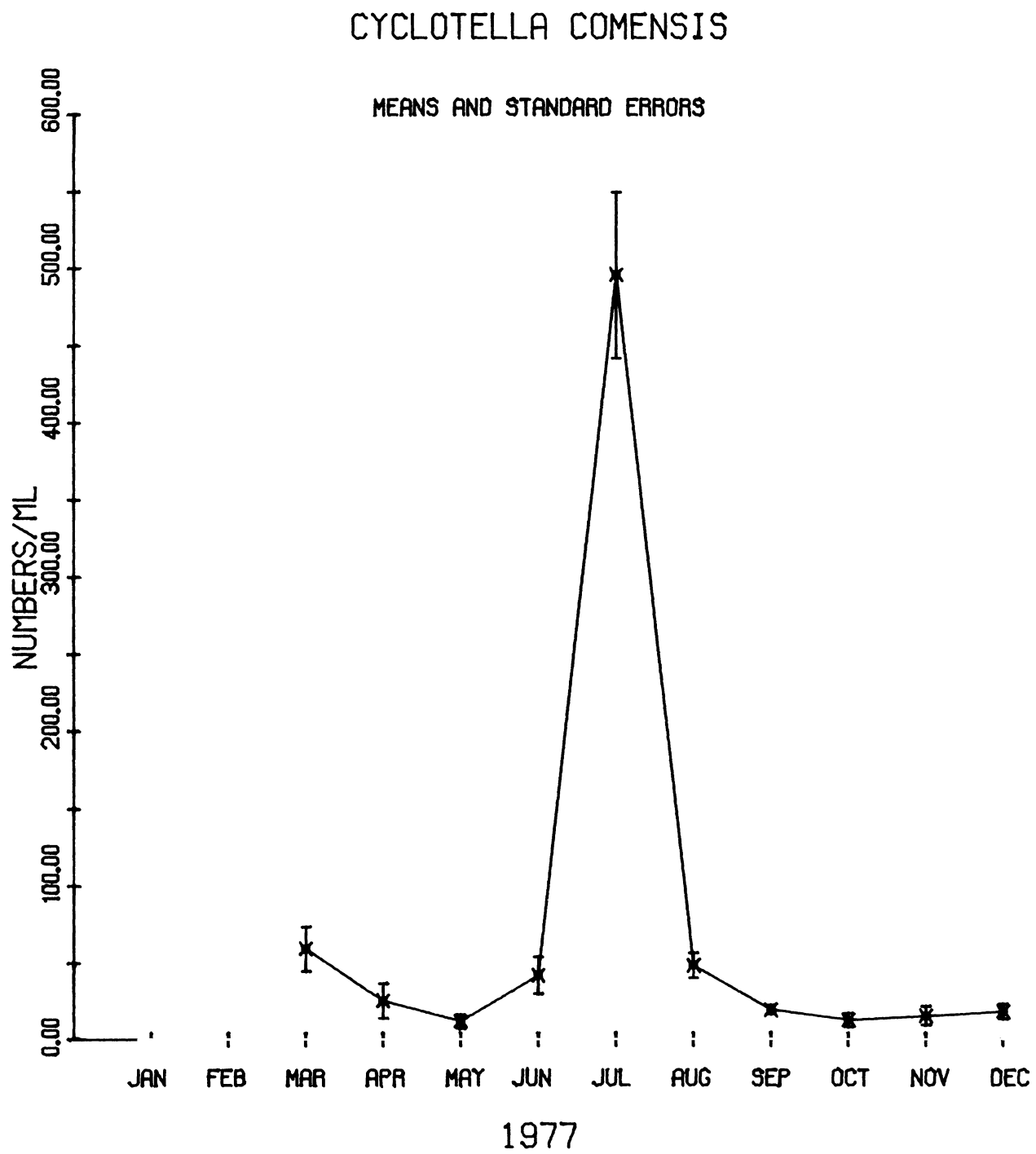


FIG. 34. Variation of Cyclotella comensis numbers during 1977.

Cyclotella stelligera--

This species has decreased in abundance since 1975 (Figures 35-37). It is most probable that this behavior is a response to changing nutrient conditions in the lake. This is similar to what others have observed for southern Lake Michigan (Tarapchak and Stoermer 1976). The yearly fluctuations have been basically consistent, with a spring bloom in April or March followed by a bloom in July. In 1975 (December), there was a large population which carried over to January 1976. This is typical of other centric diatoms for this time period.

Rhizosolenia gracilis--

The population of this centric diatoms has varied considerably in 3 years (Figures 38-39). It was dominant only in 1976. The population increased about 91% in 1976 (maximum abundance 270 cells per mL) and then dropped to an abundance of less than 13 cells per mL in 1977. Without future data the significance of this recent decline cannot be correctly evaluated. All 3 years were typified by spring or early summer maxima and the absence of a fall bloom. The increase in abundance in July 1976 was most likely due to a nutrient-rich upwelling.

Stephanodiscus minutus--

This alga decreased in abundance in 1977 after having equal mean densities in 1975 and 1976 (Figures 40-42). The large decrease in 1977 is somewhat consistent with a 35% decrease in the total number of centric diatoms for that time period. This differs to some extent from the lake data for this area

## CYCLOTELLA STELLIGERA

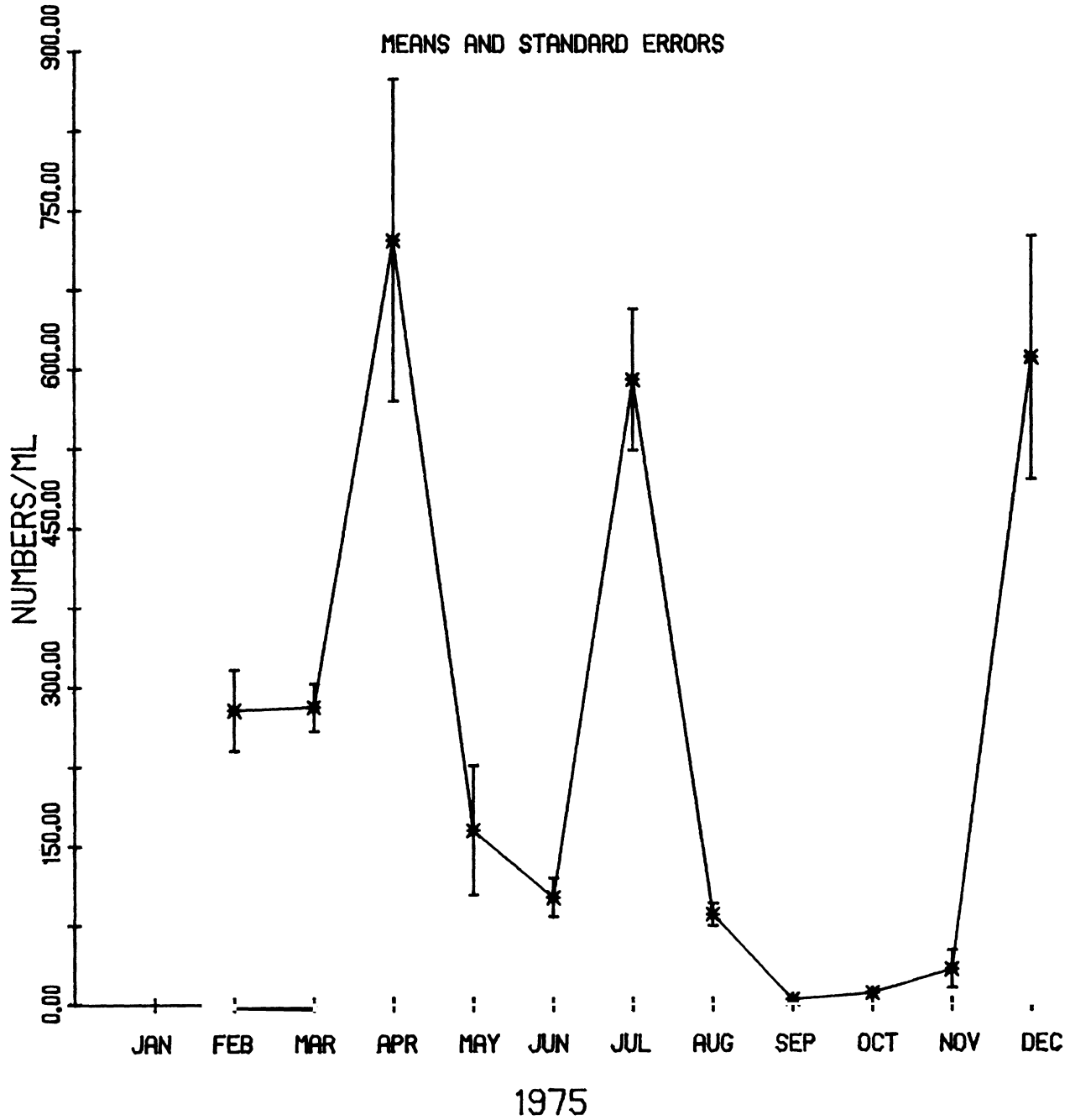


FIG. 35. Variation of Cyclotella stelligera numbers during 1975.

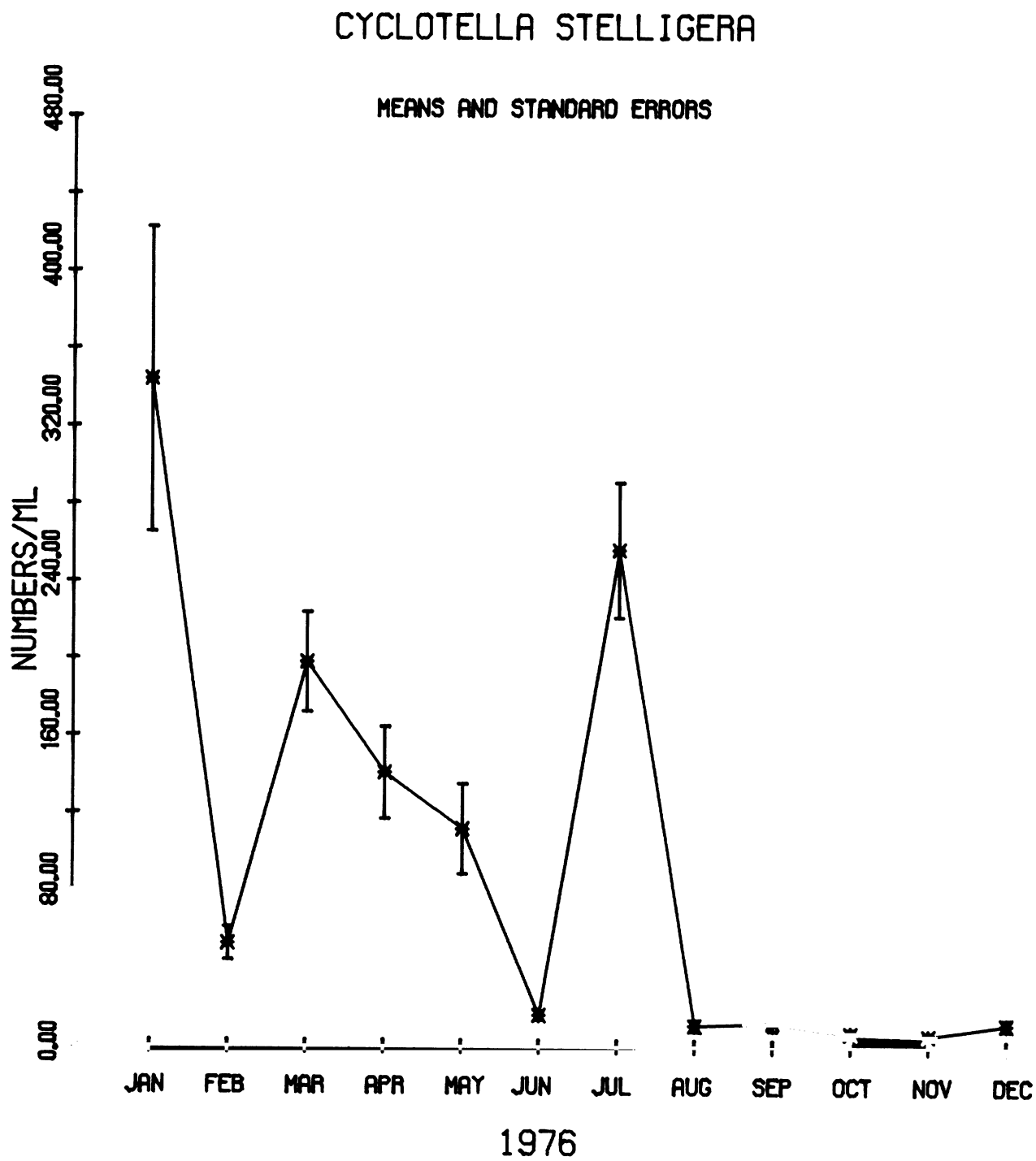


FIG. 36. Variation of Cyclotella stelligera numbers during 1976.

# CYCLOTELLA STELLIGERA

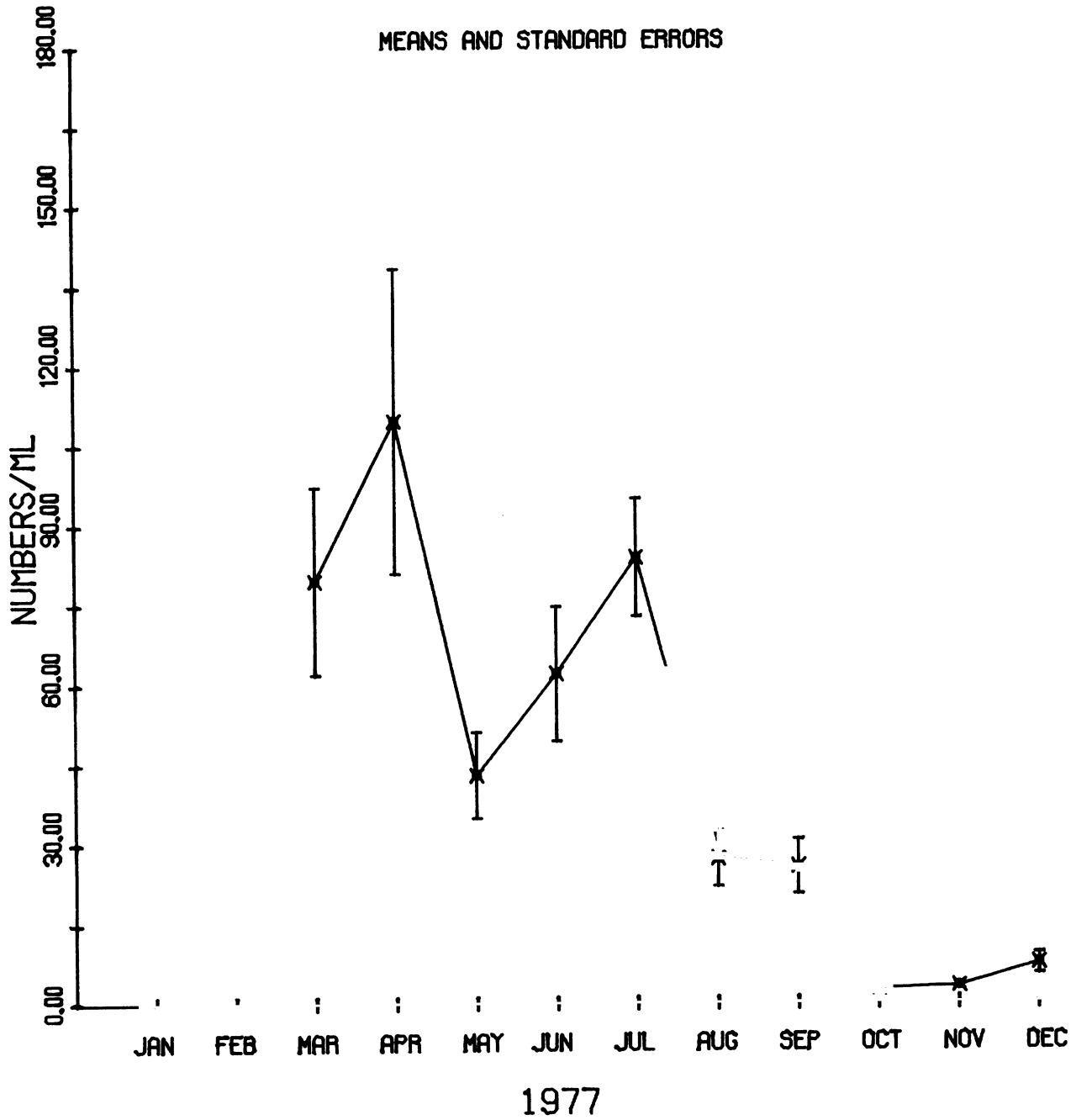


FIG. 37. Variation of Cyclotella stelligera numbers during 1977.

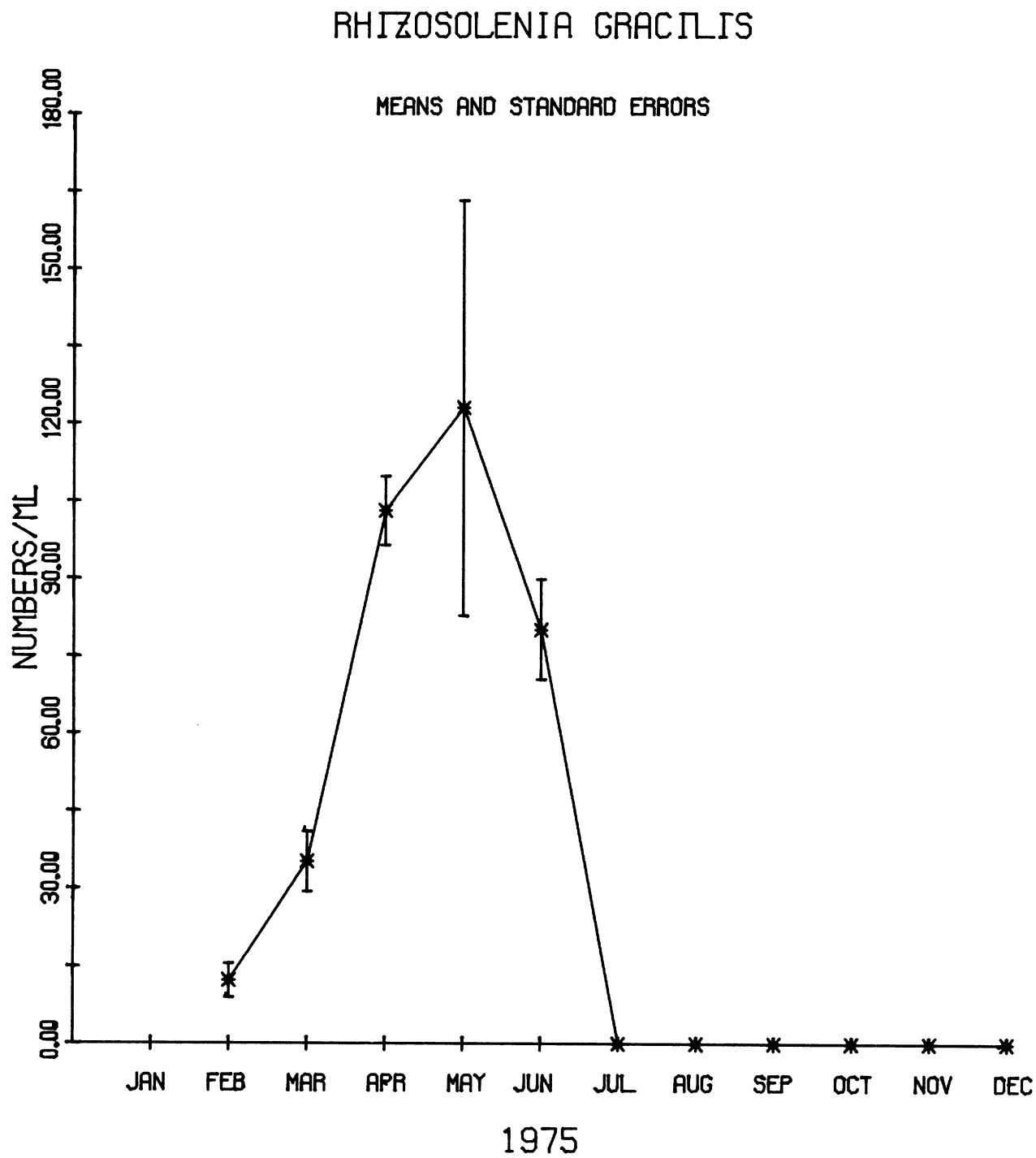


FIG. 38. Variation of Rhizosolenia gracilis numbers during 1975.

## RHIZOSOLENIA GRACILIS

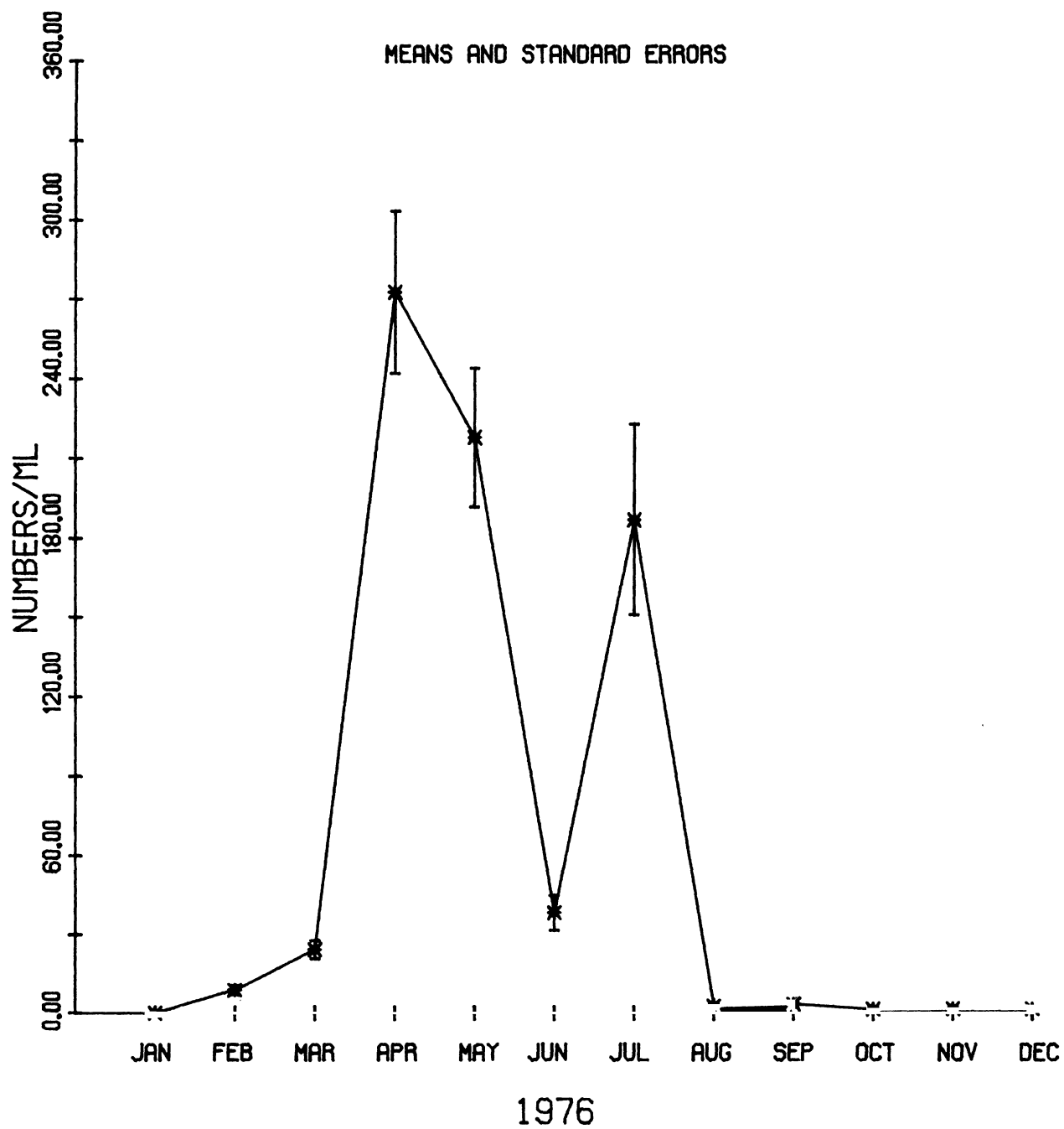


FIG. 39. Variation of Rhizosolenia gracilis numbers during 1976.



## STEPHANODISCUS MINUTUS

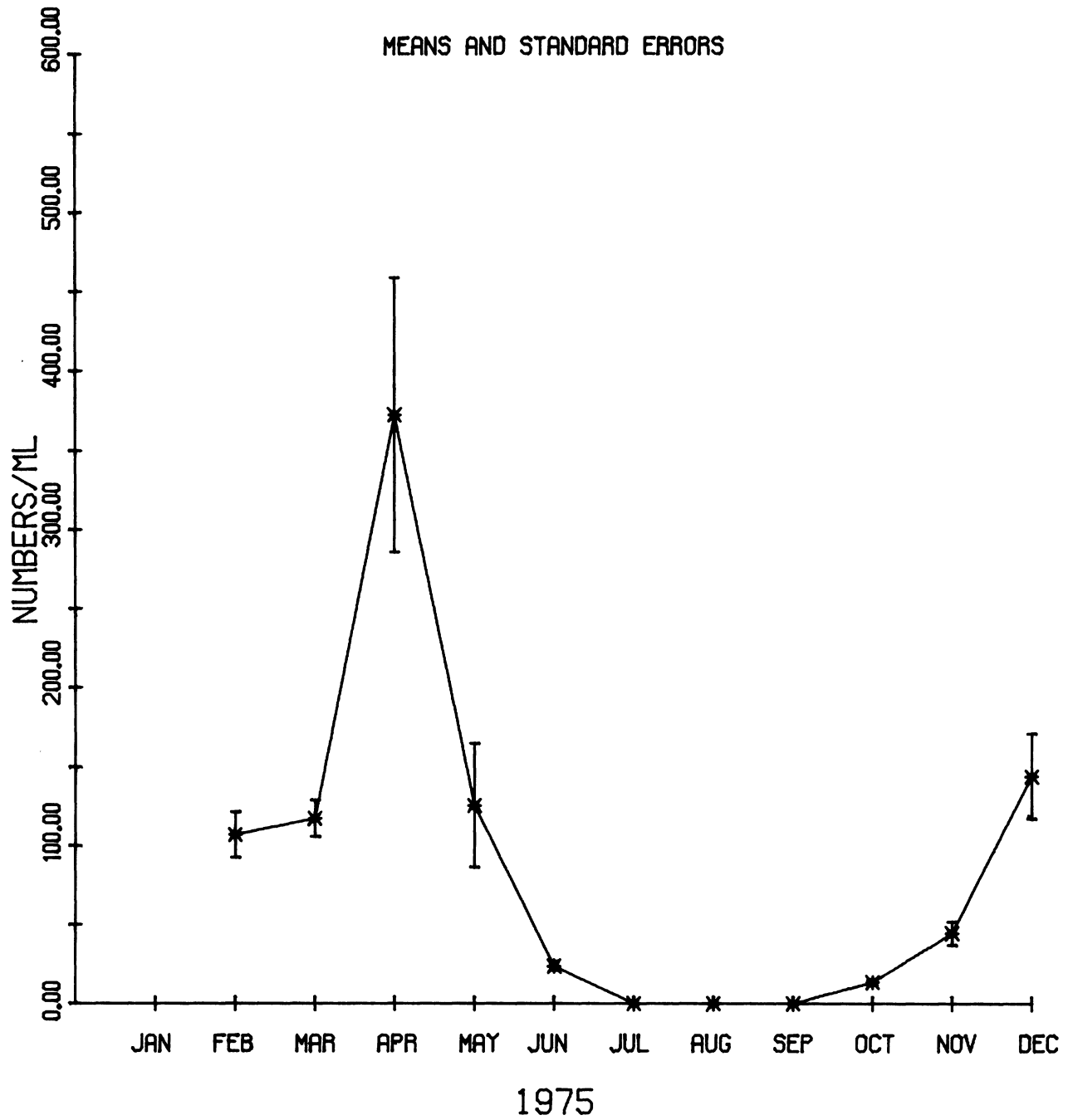


FIG. 40. Variation of Stephanodiscus minutus numbers during 1975.

## STEPHANODISCUS MINUTUS

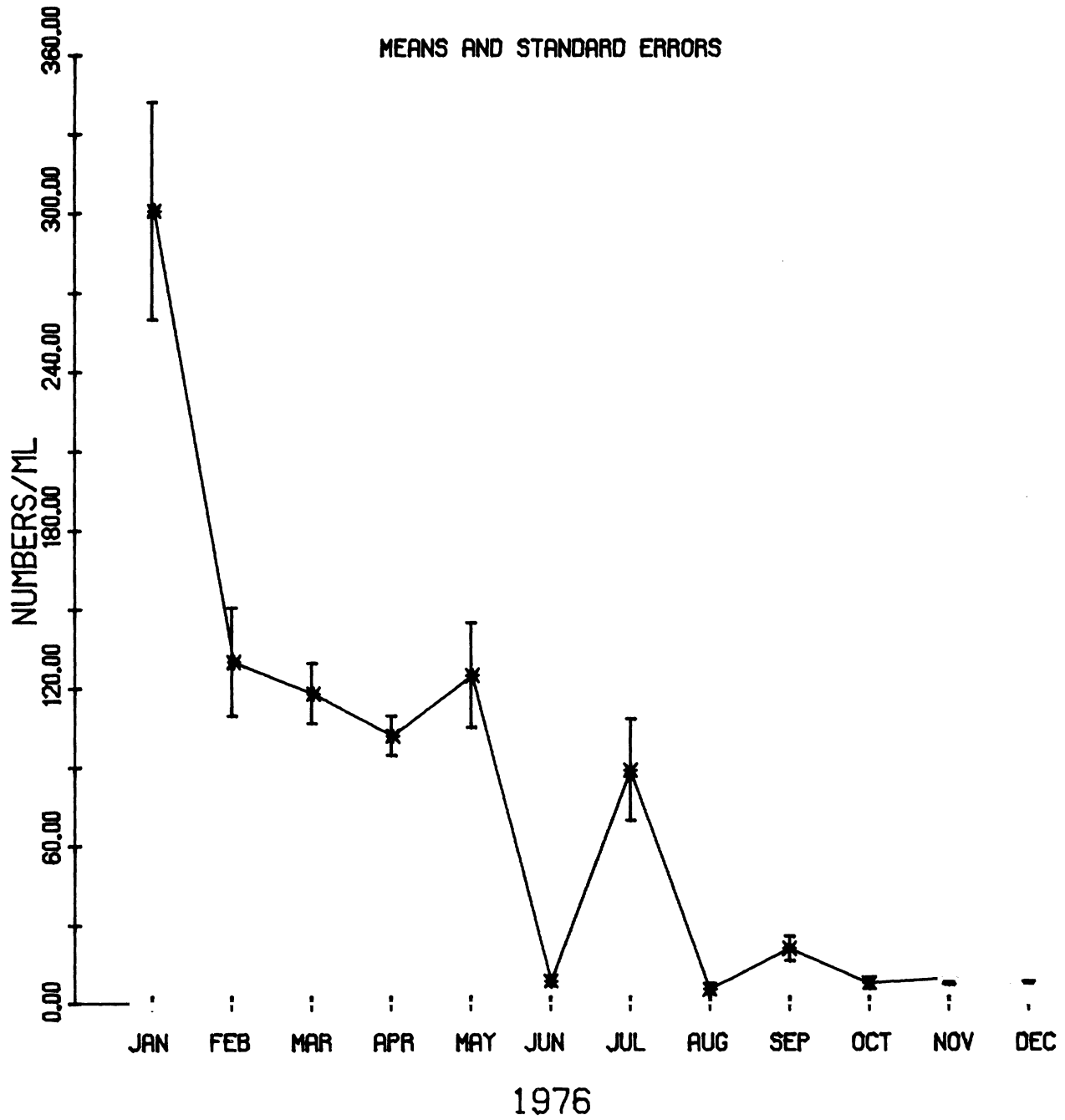


FIG. 41. Variation of Stephanodiscus minutus numbers during 1976.

# STEPHANODISCUS MINUTUS

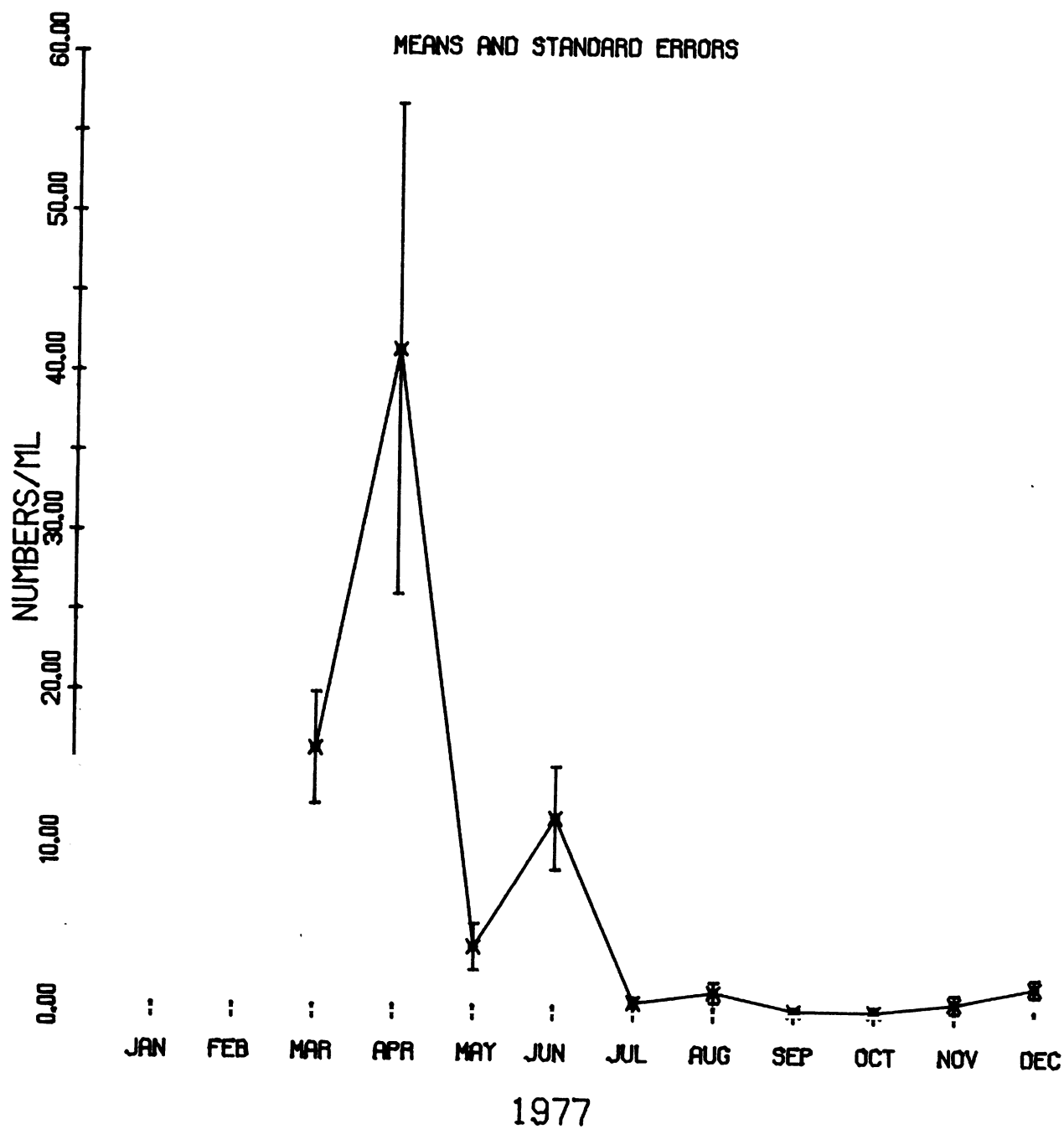


FIG. 42. Variation of Stephanodiscus minutus numbers during 1977.

(Ayers and Wiley 1979) which declined only slightly. Once again, future data need to be considered to determine if these data reflect a real decrease in the population.

Stephanodiscus subtilus--

1976 was the only year in which this species occurred as a dominant (Figures 43-44). The populations were notably lower in both 1975 and 1977. As has been the case with several species, this variable behavior makes it difficult to make any comments about power plant effects.

Stephanodiscus tenuis--

From 1975 to 1977 the mean abundance of this species decreased (Figures 45-47). Also in 1976 and 1977, this species never appeared as a dominant in the lake control station data (Ayers and Wiley 1979), although it was dominant in 1974 and 1975. The population decrease may be part of a natural variation and not an effect of the Cook Plant.

Asterionella formosa--

In 1976 and 1977, this species was dominant in the population (Figures 48-50). In the lake data (Ayers and Wiley 1979), it only occurred as a dominant in 1976. In 1977 the dominance only occurred in November, a month when lake control station data for this area are not available. It is probable that the peak would have also occurred at the lake stations as part of the late fall diatom bloom. The cells numbers increased in 1976 and declined markedly

# STEPHANODISCUS SUBTILIS

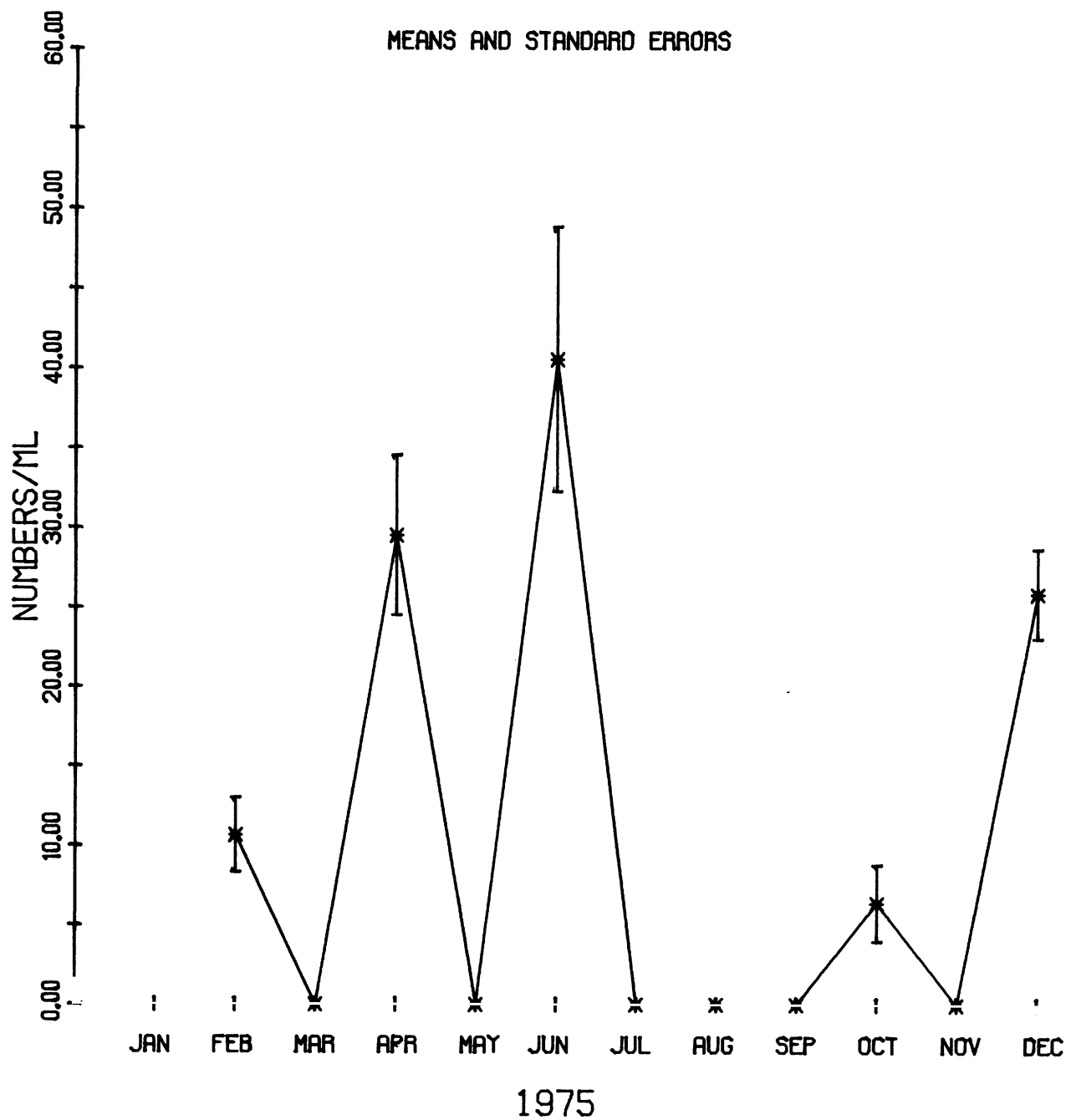


FIG. 43. Variation of Stephanodiscus subtilis numbers during 1975.

## STEPHANODISCUS SUBTILIS

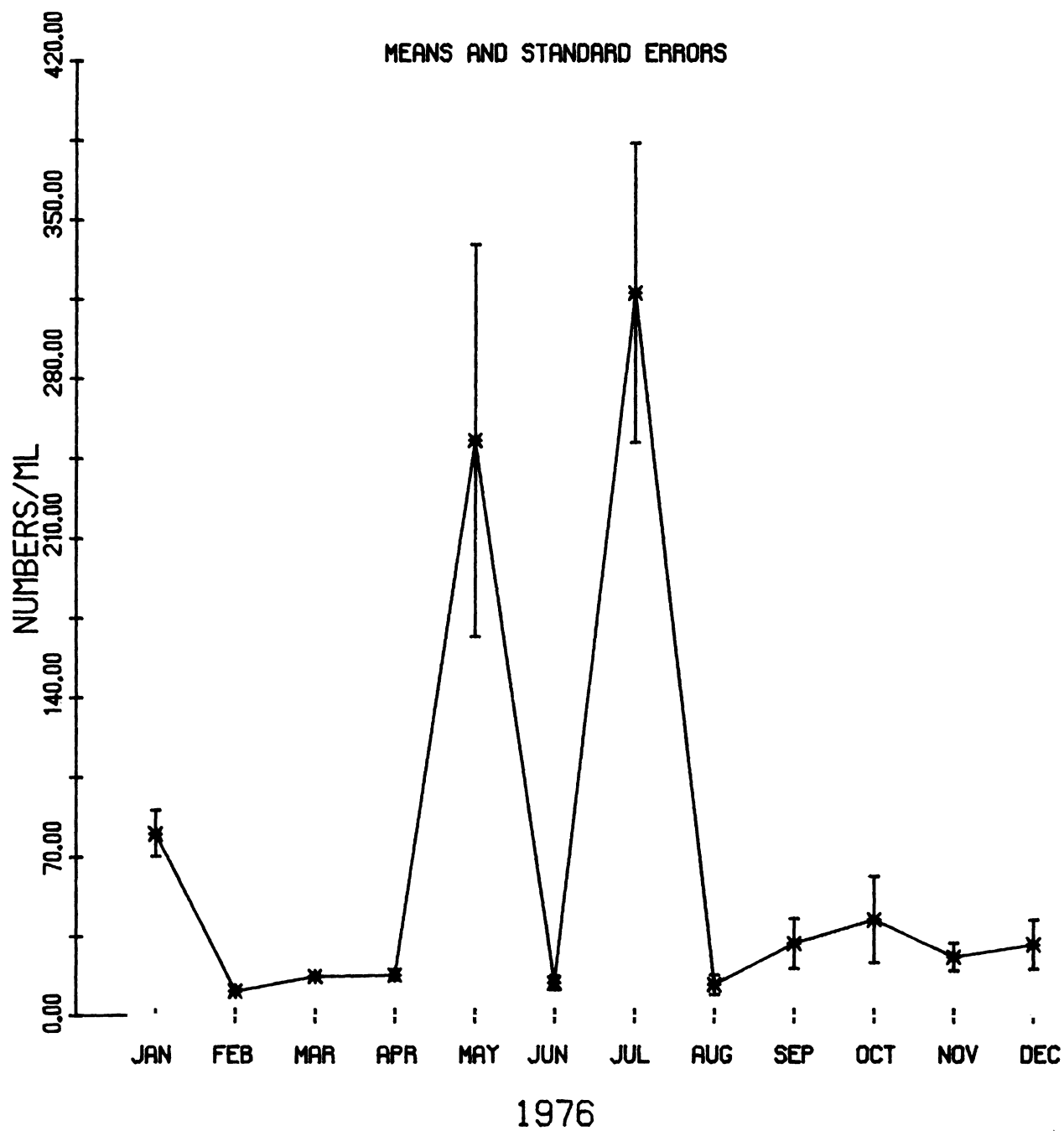


FIG. 44. Variation of Stephanodiscus subtilis numbers during 1976.

## STEPHANODISCUS TENUIS

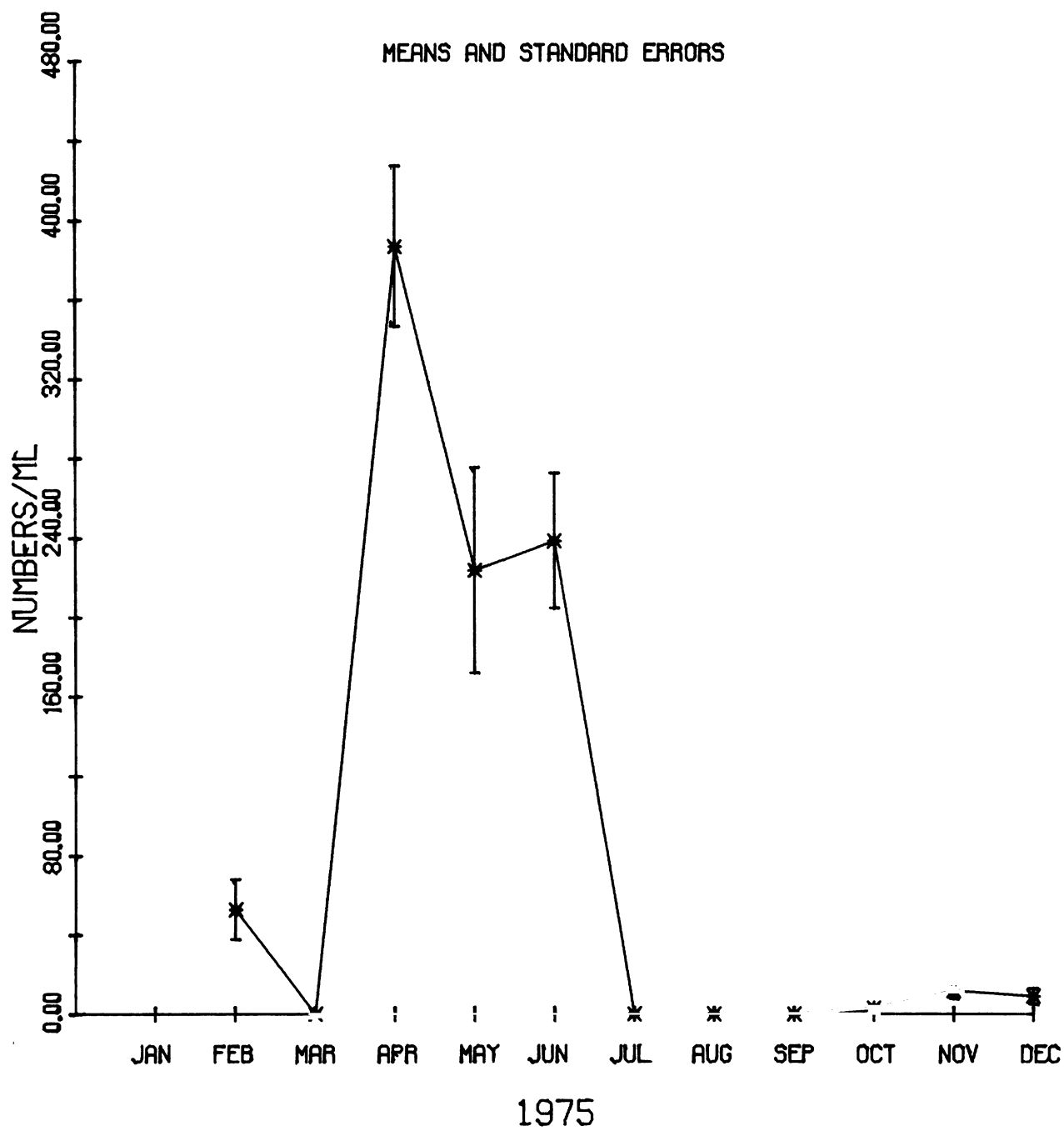


FIG. 45. Variation of Stephanodiscus tenuis numbers during 1975.

## STEPHANODISCUS TENUIS

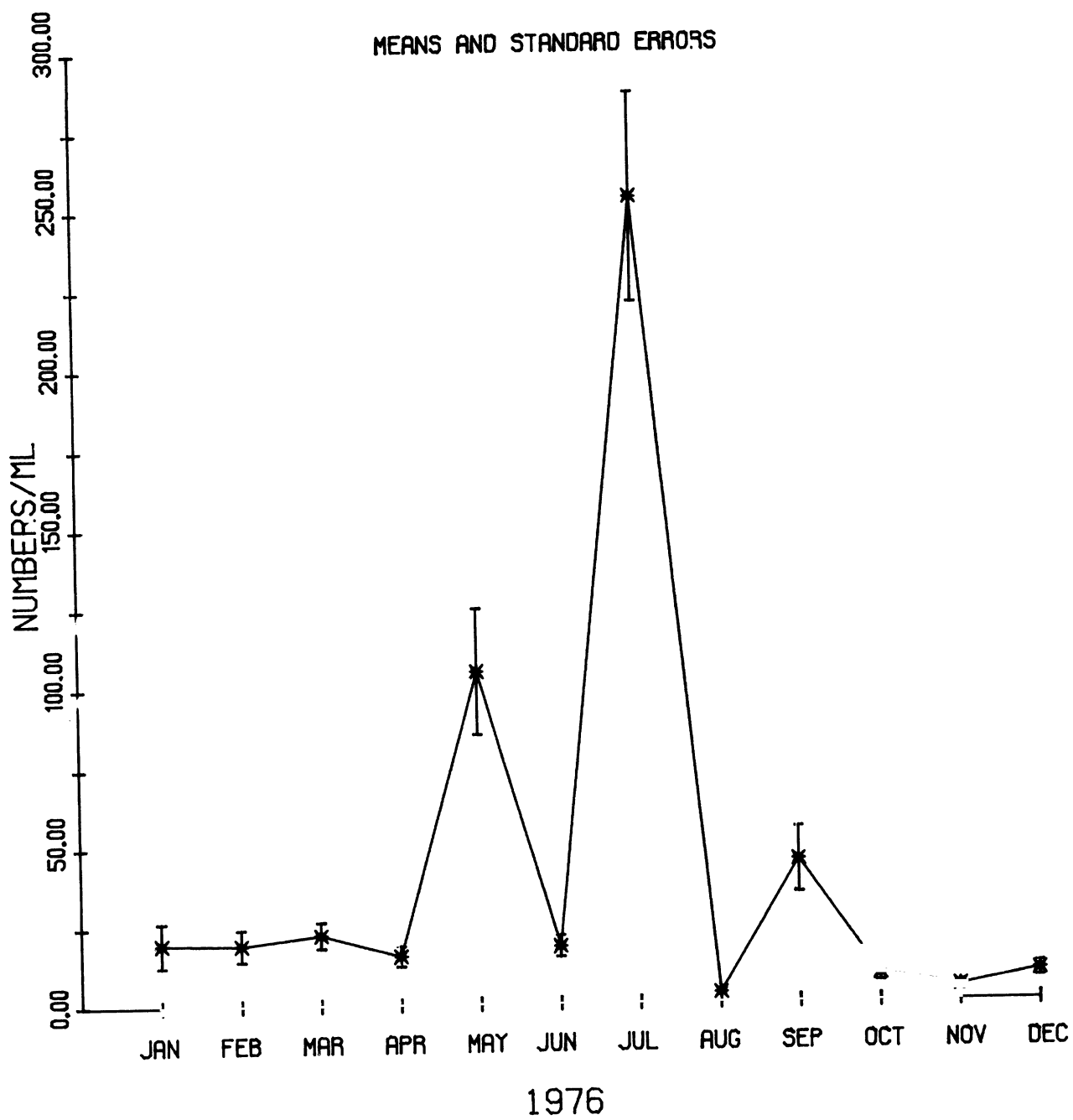


FIG. 46. Variation of Stephanodiscus tenuis numbers during 1976.



## STEPHANODISCUS TENUIS

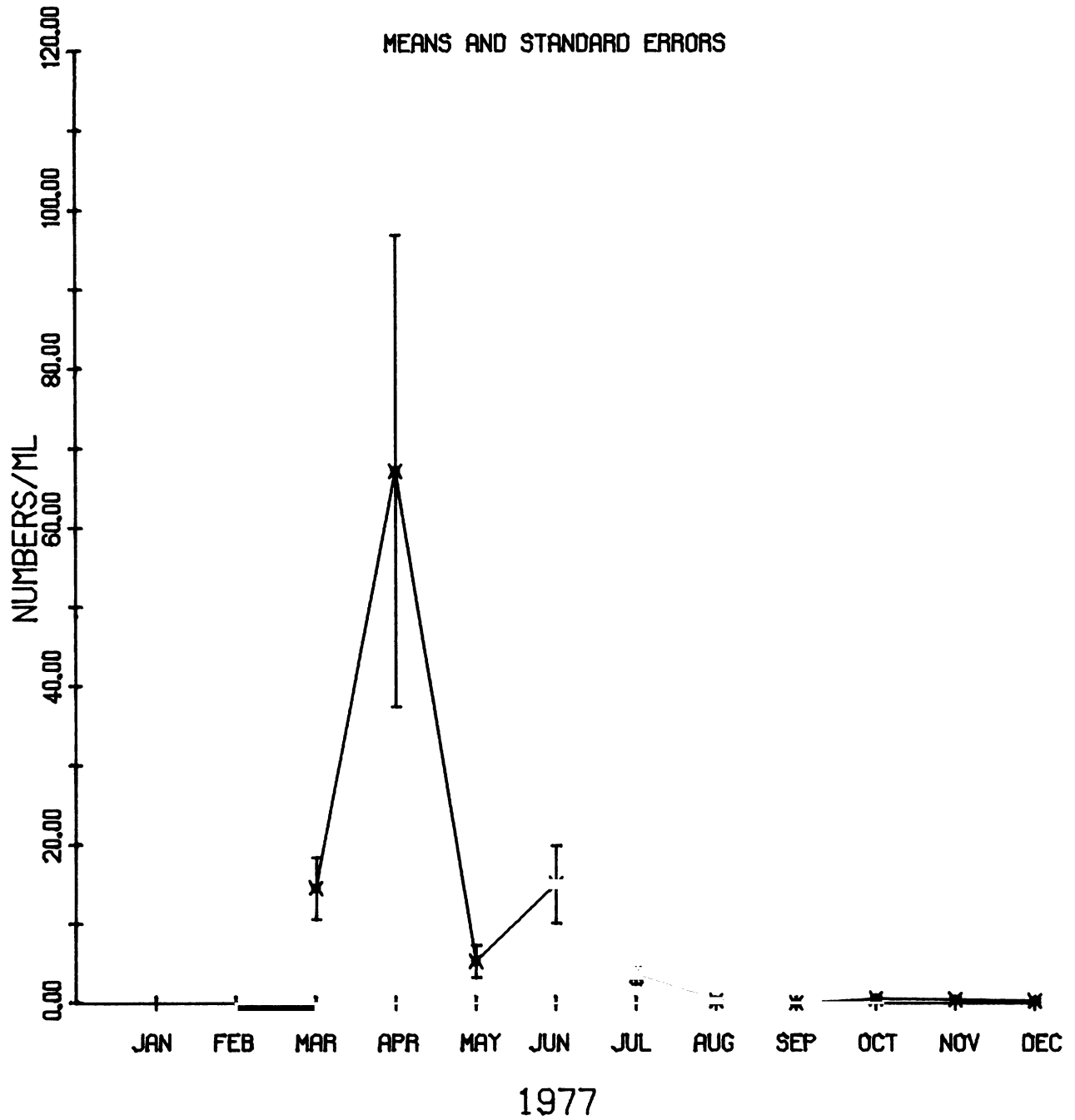


FIG. 47. Variation of Stephanodiscus tenuis numbers during 1977.

# ASTERIONELLA FORMOSA

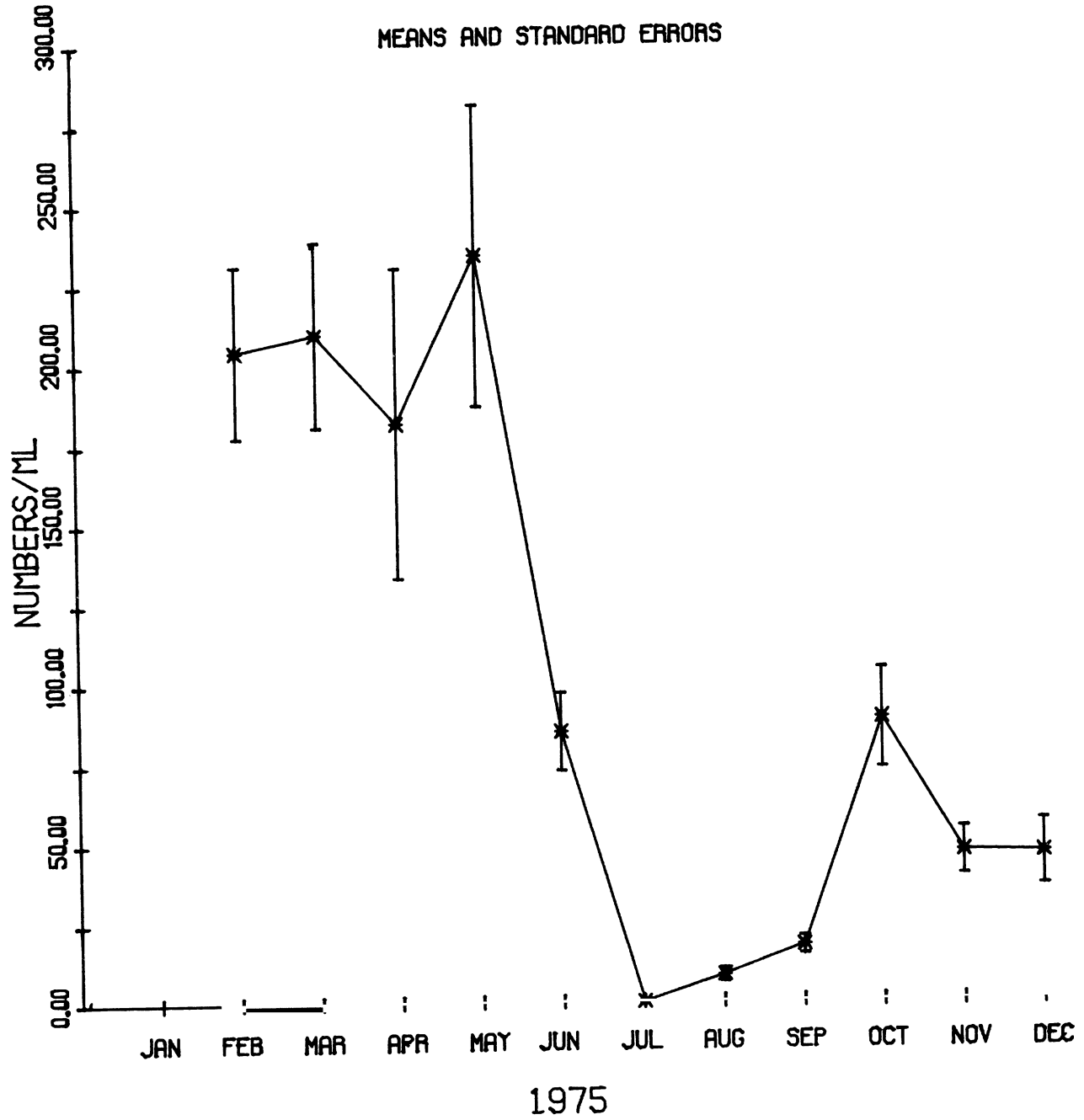


FIG. 48. Variation of Asterionella formosa numbers during 1975.

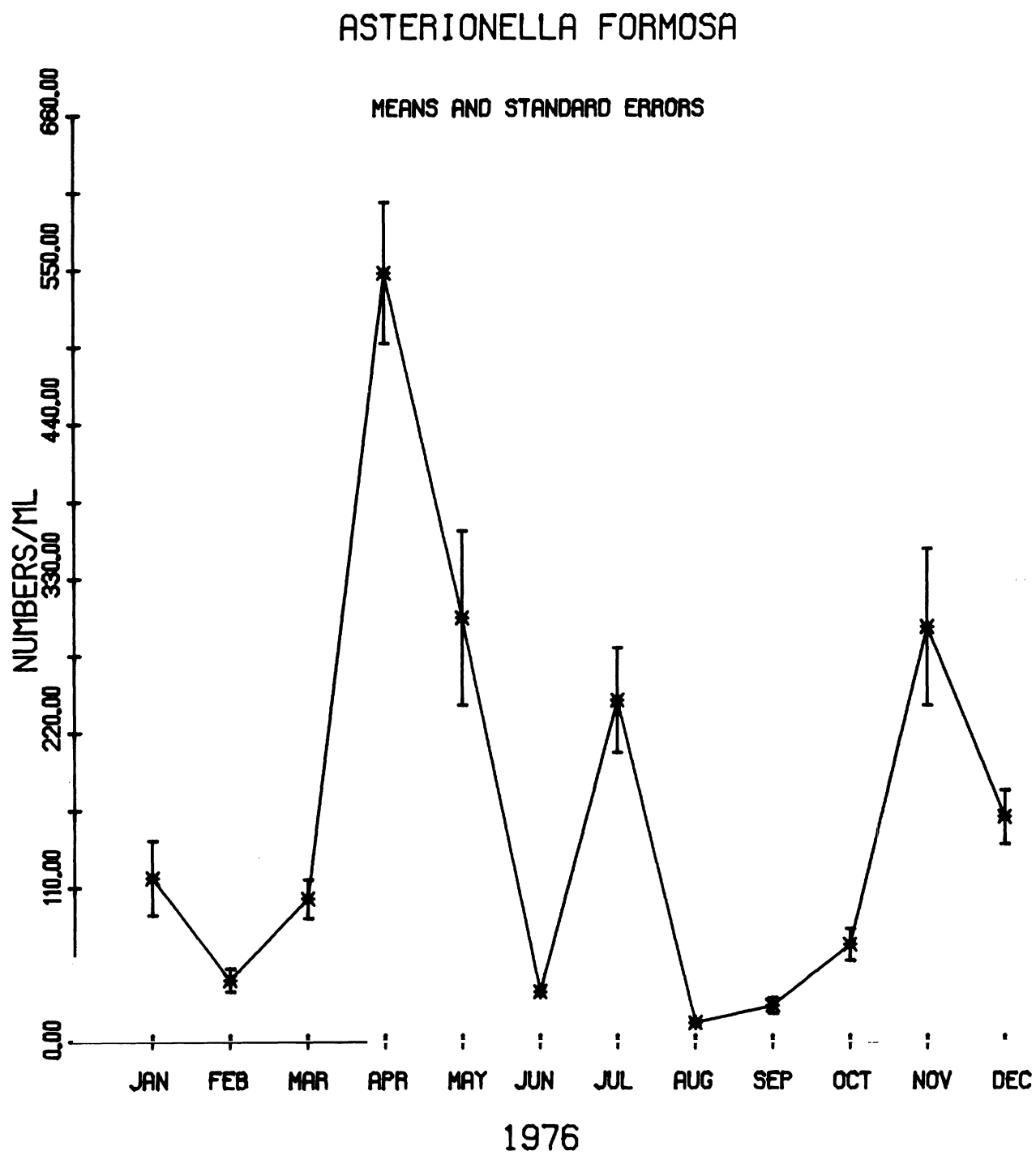


FIG. 49. Variation of Asterionella formosa numbers during 1976.

# ASTERIONELLA FORMOSA

MEANS AND STANDARD ERRORS

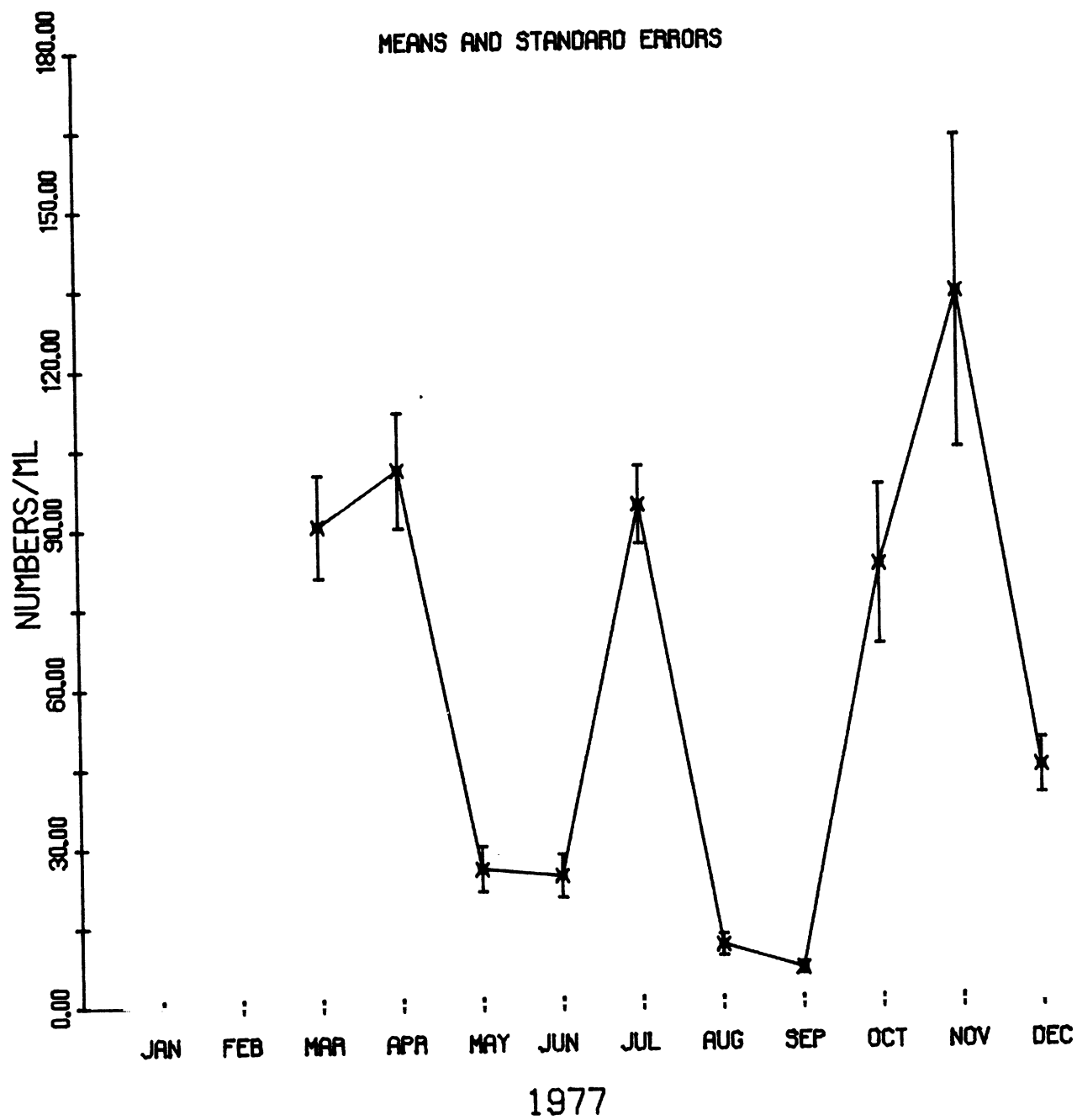


FIG. 50. Variation of Asterionella formosa numbers during 1977.

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## DIATOMA TENUE V. ELONGATUM

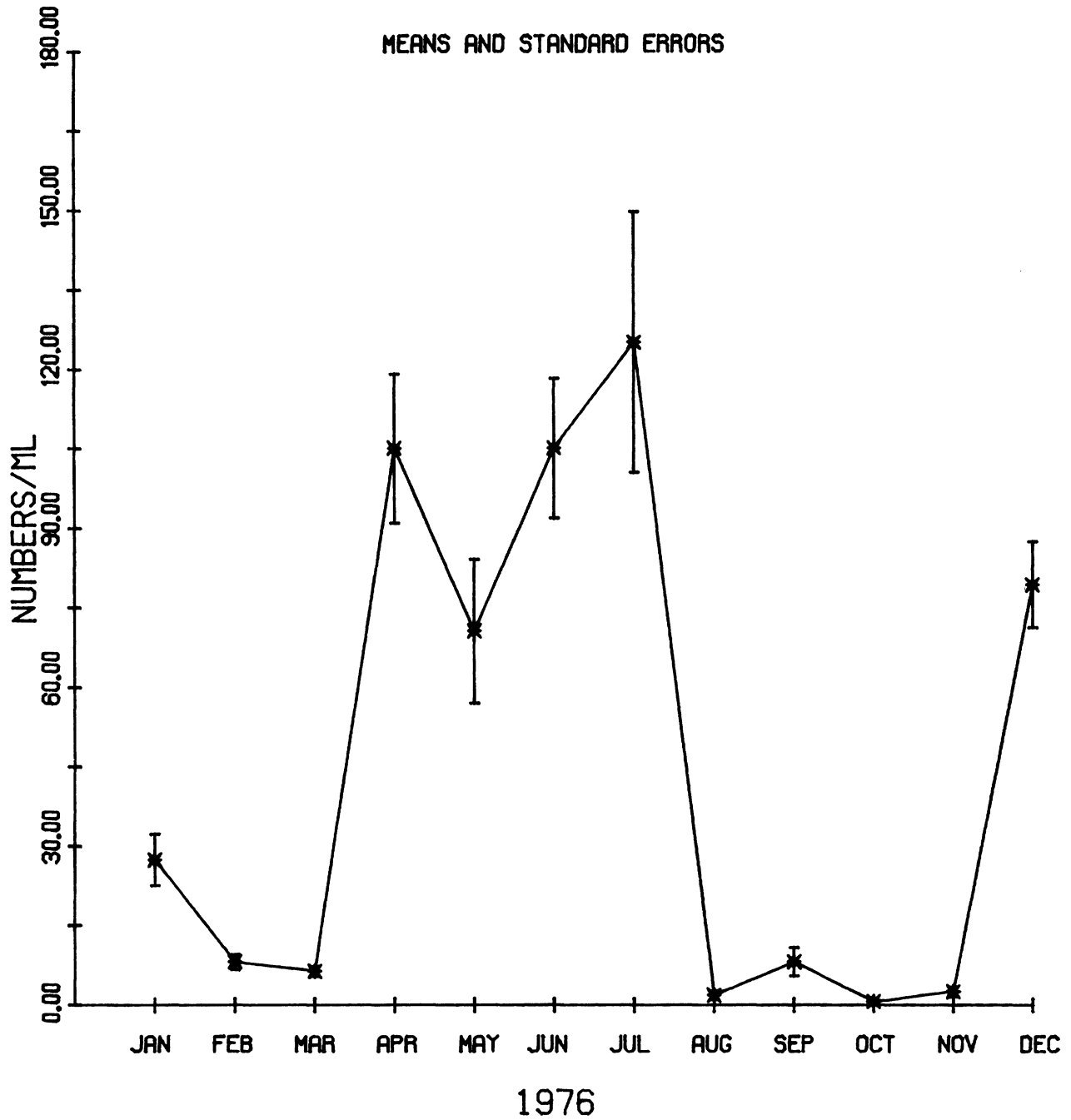


FIG. 52. Variation of Diatoma tenue v. elongatum numbers during 1976.

## DIATOMA TENUE V. ELONGATUM

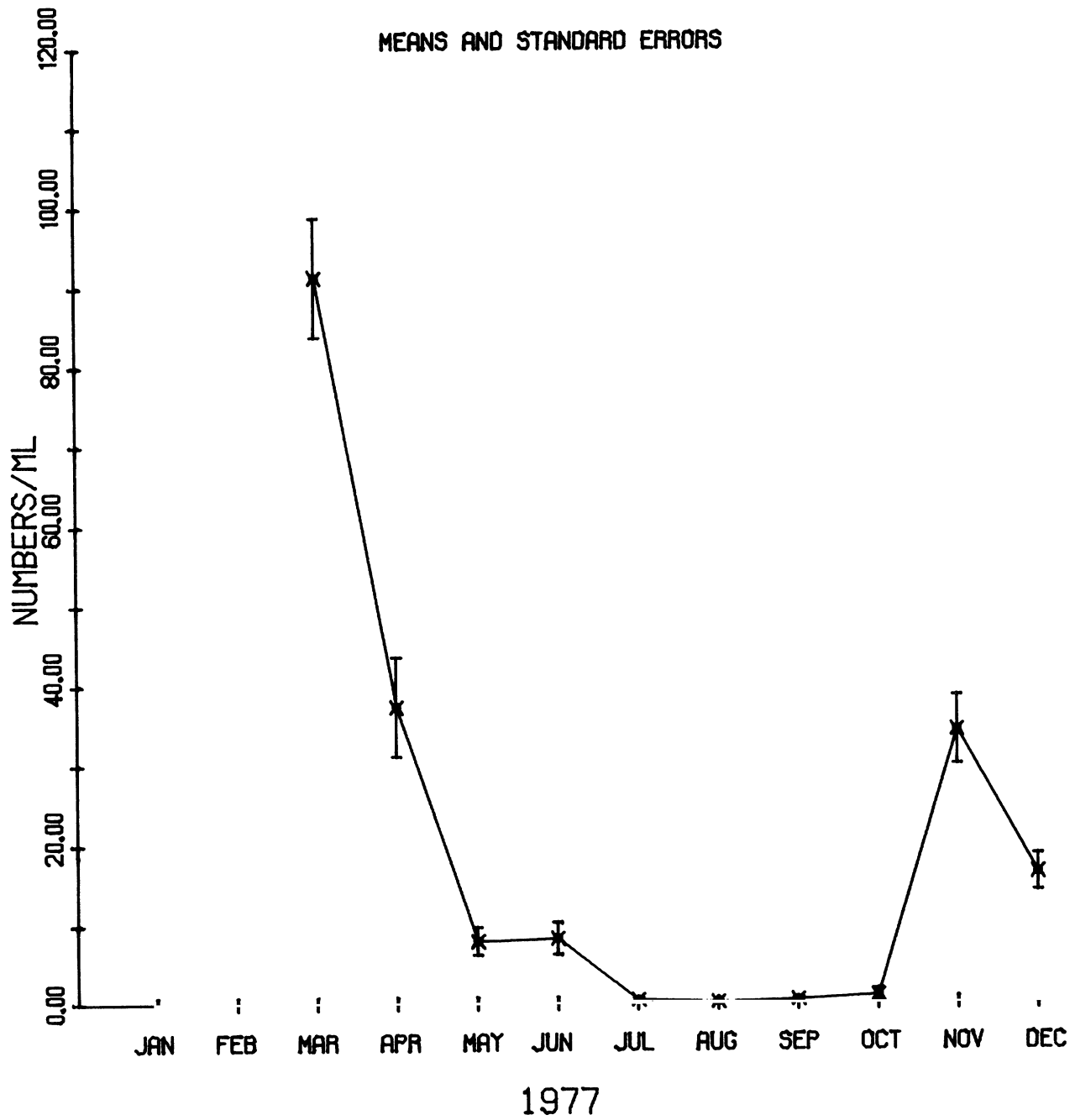


FIG. 53. Variation of Diatoma tenue v. elongatum numbers during 1977.



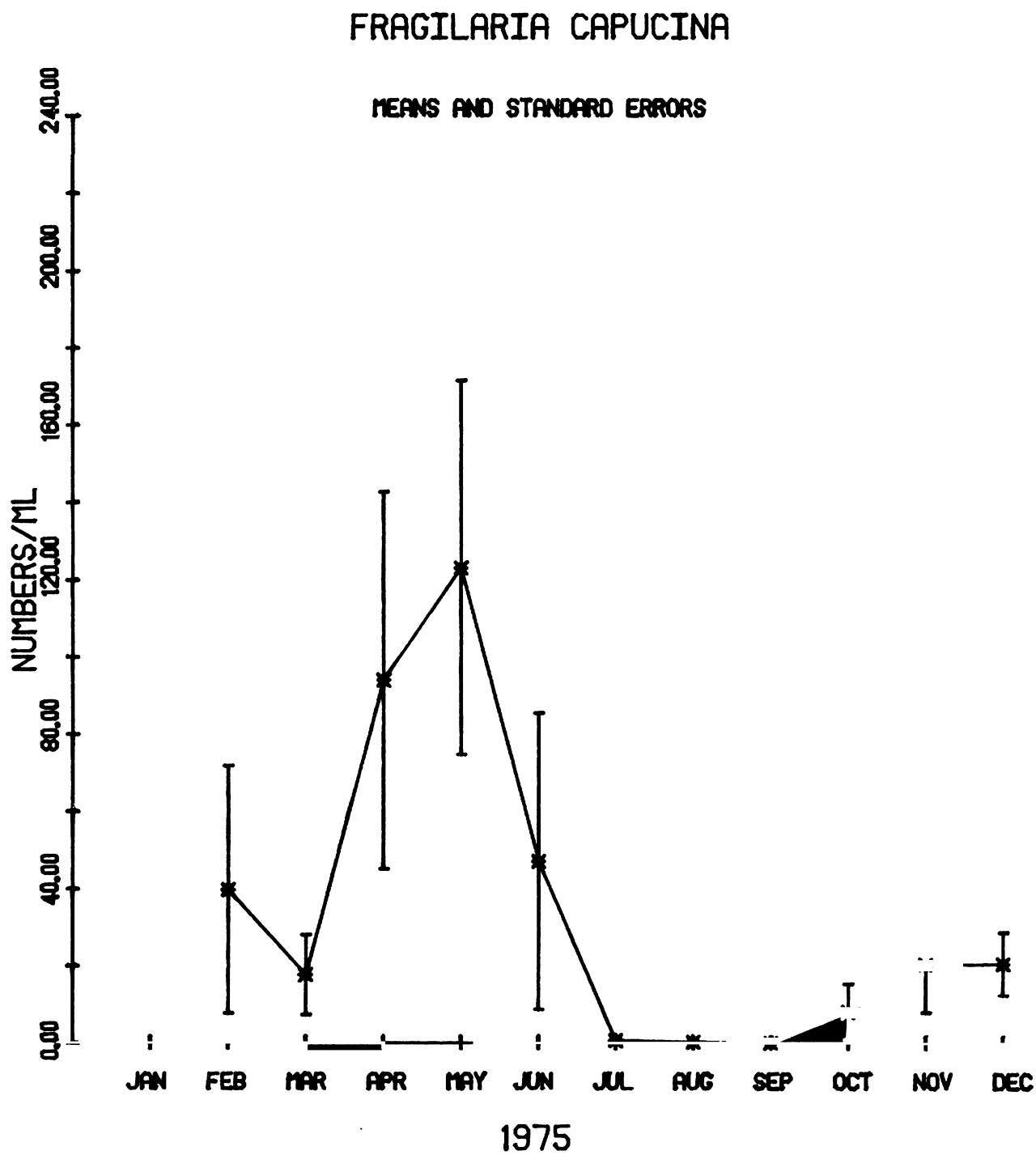


FIG. 54. Variation of Fragilaria capucina numbers during 1975.

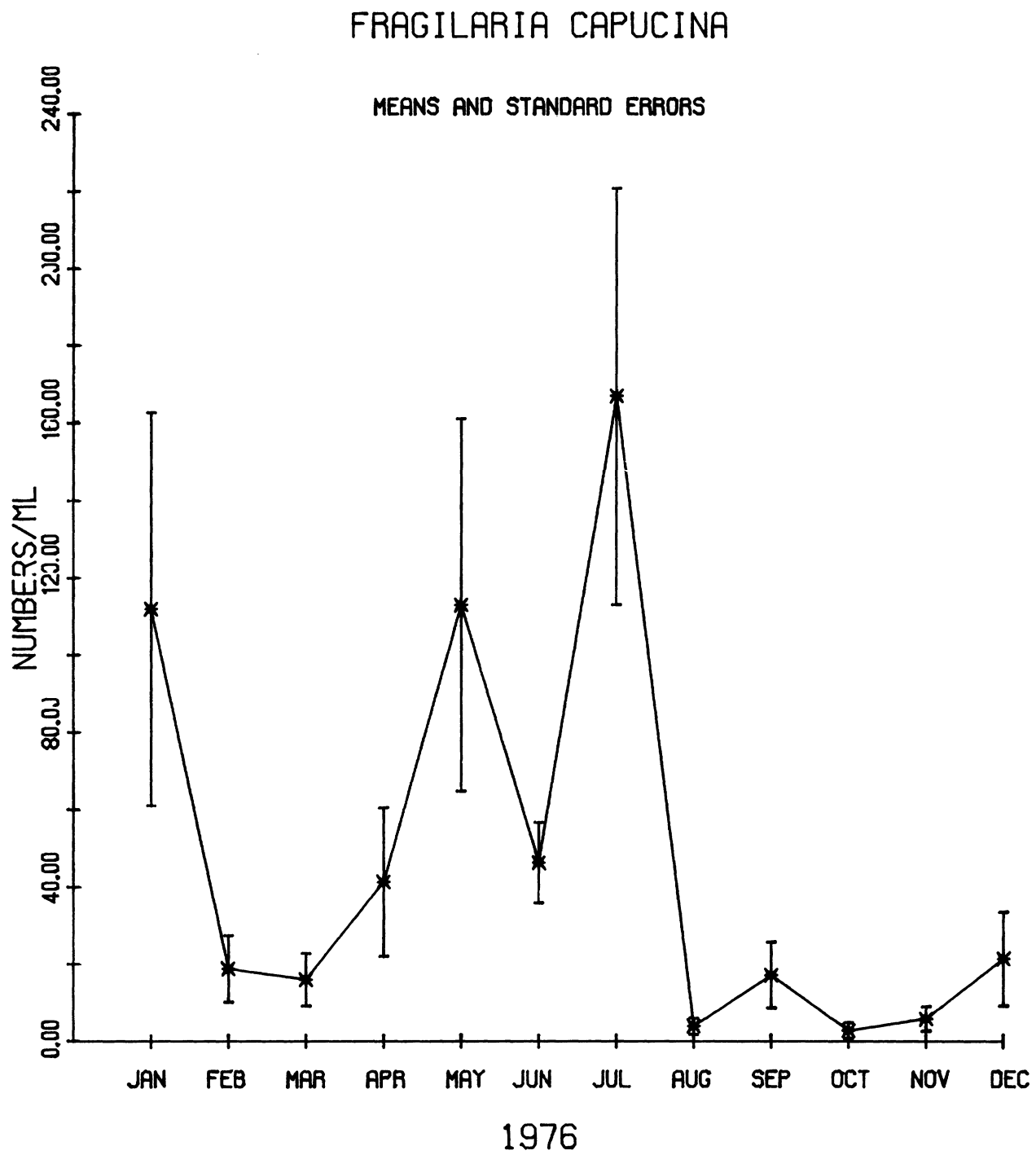


FIG. 55. Variation of Fragilaria capucina numbers during 1976.

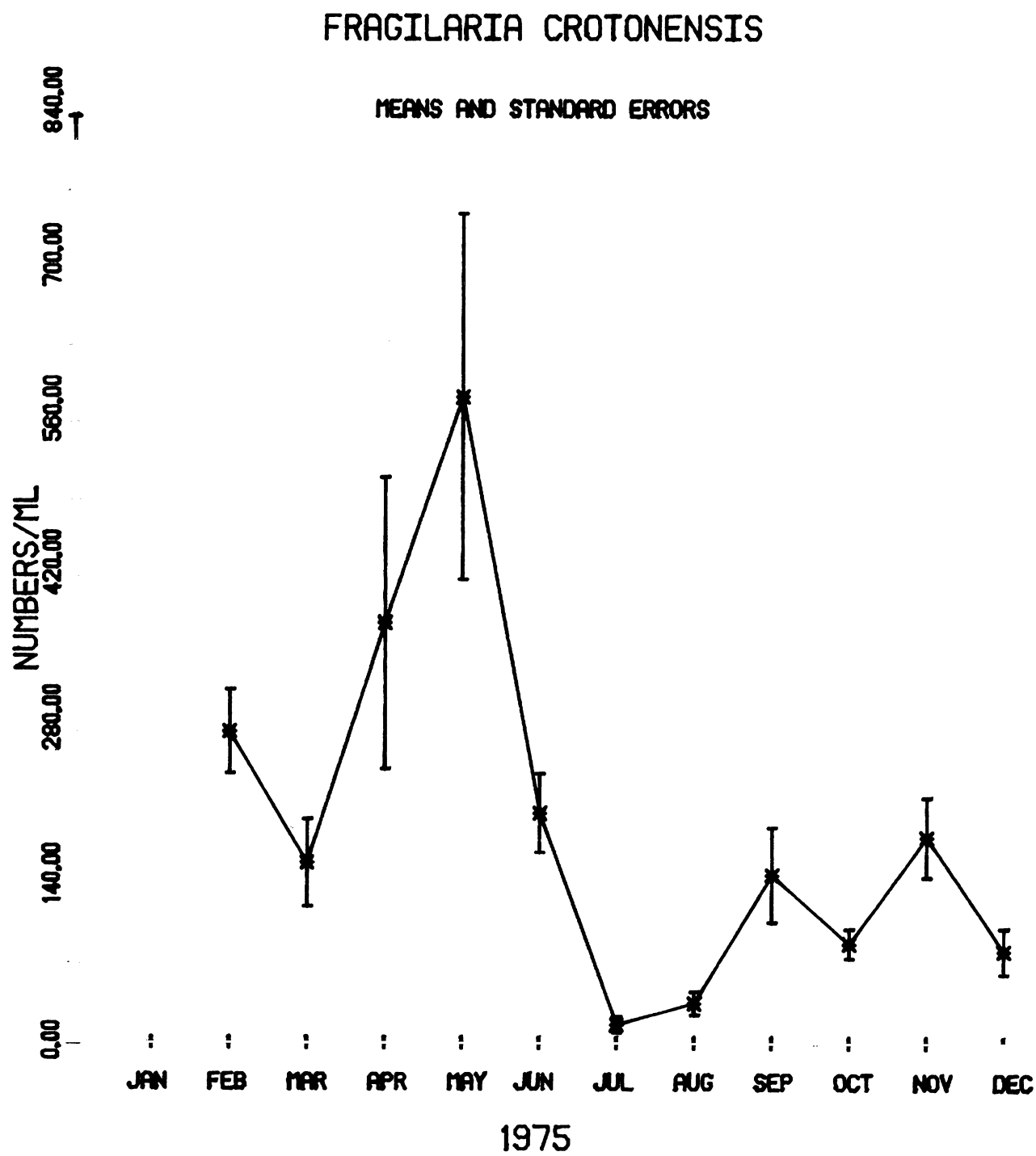


FIG. 56. Variation of Fragilaria crotonensis numbers during 1975.

## FRAGILARIA CROTONENSIS

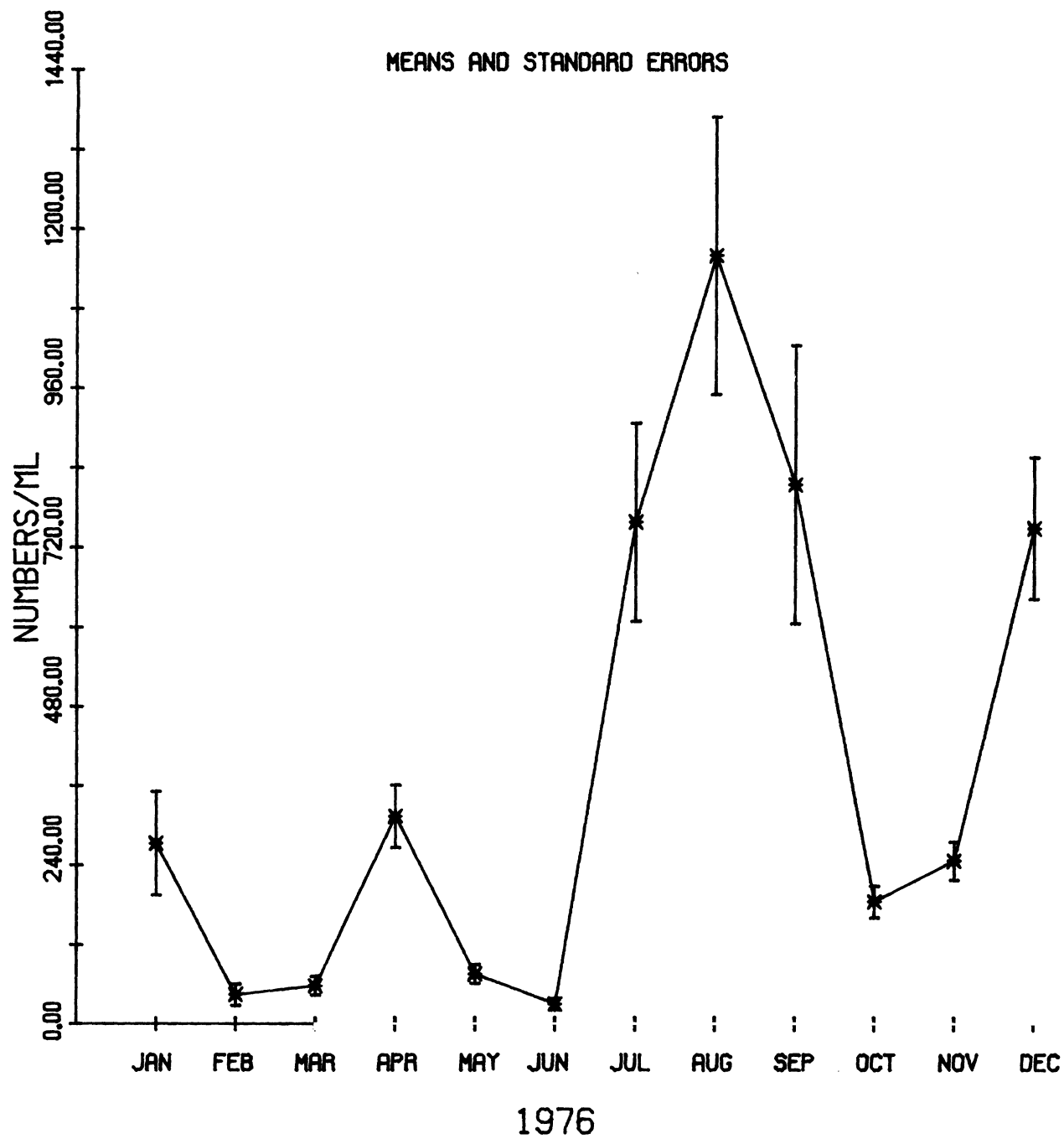


FIG. 57. Variation of Fragilaria crotonensis numbers during 1976.

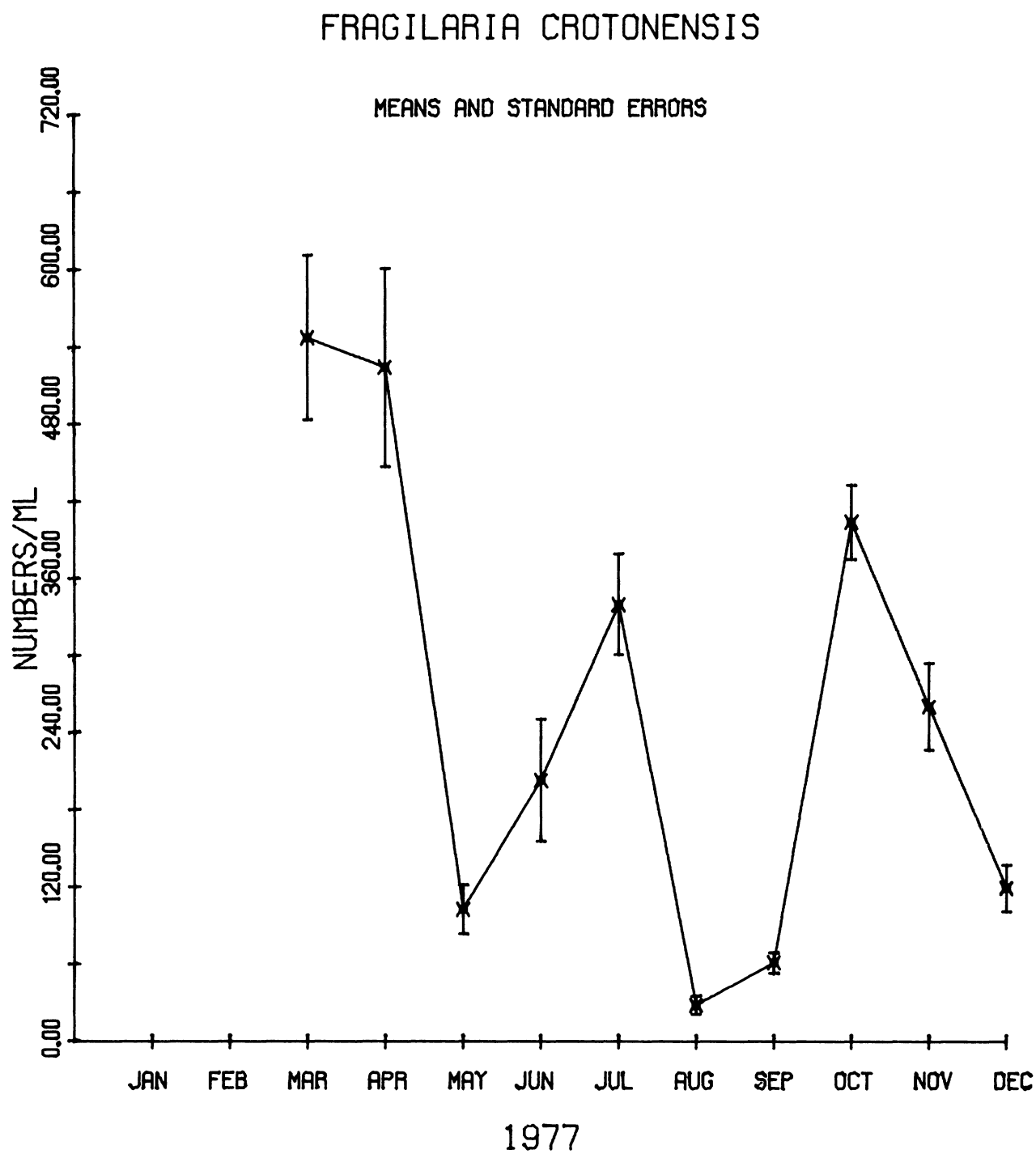


FIG. 58. Variation of Fragilaria crotonensis numbers during 1977.

appeared as a dominant in spring, fall, and winter. This is characteristic of its behavior in the lake data (Ayers and Wiley 1979).

Fragilaria intermedia--

This species occurred as a dominant only in 1975 in both lake and entrainment samples (Figures 59-61). Since it had not appeared as a dominant since 1970 in the lake samples (Ayers and Wiley 1979), it is probable that this occurrence is only a temporal one and not of great significance. The large population in July 1976, although not dominant, was probably due to the strong upwelling which occurred at that time.

Fragilaria intermedia v. fallax--

The only year in which this alga experienced a high density was 1976 (Figures 62-63). It was dominant in July. As has been previously mentioned, a large upwelling occurred at this time which affected the growth of many phytoplankton species, especially the diatoms, which may be nutrient-limited due to a low dissolved silica concentration at this time of the year.

Tabellaria fenestrata v. intermedia--

This alga occurred as a dominant species in 1975, 1976, and 1977 (Figures 64-66). It has not been found to be as frequently dominant in the lake samples (Ayers and Wiley 1979). Its occurrence could be related to the plant's intake. Not enough is known about the ecology of this organism to determine what could be increasing its population.

## FRAGILARIA INTERMEDIA

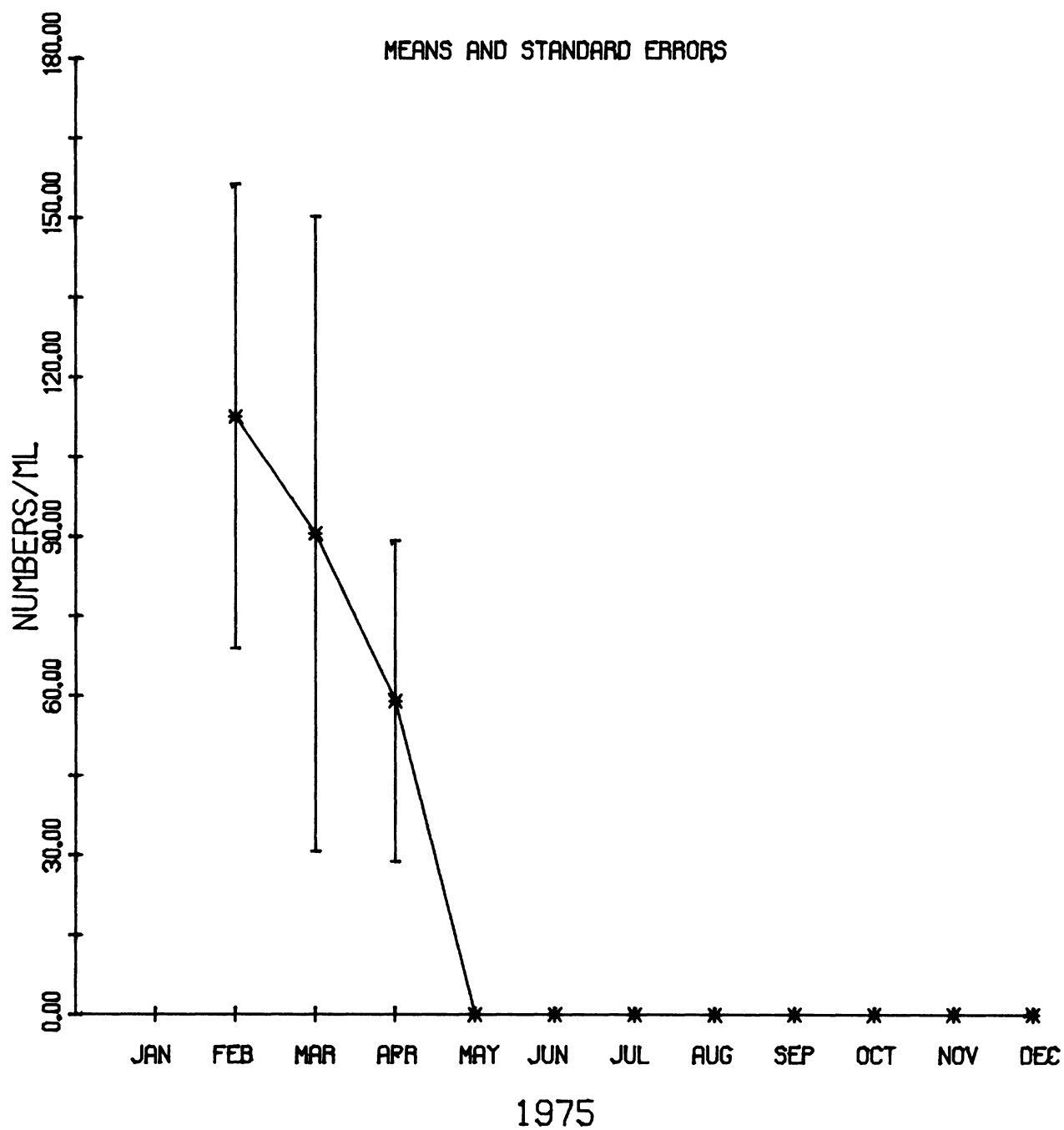


FIG. 59. Variation of Fragilaria intermedia numbers during 1975.

## FRAGILARIA INTERMEDIA

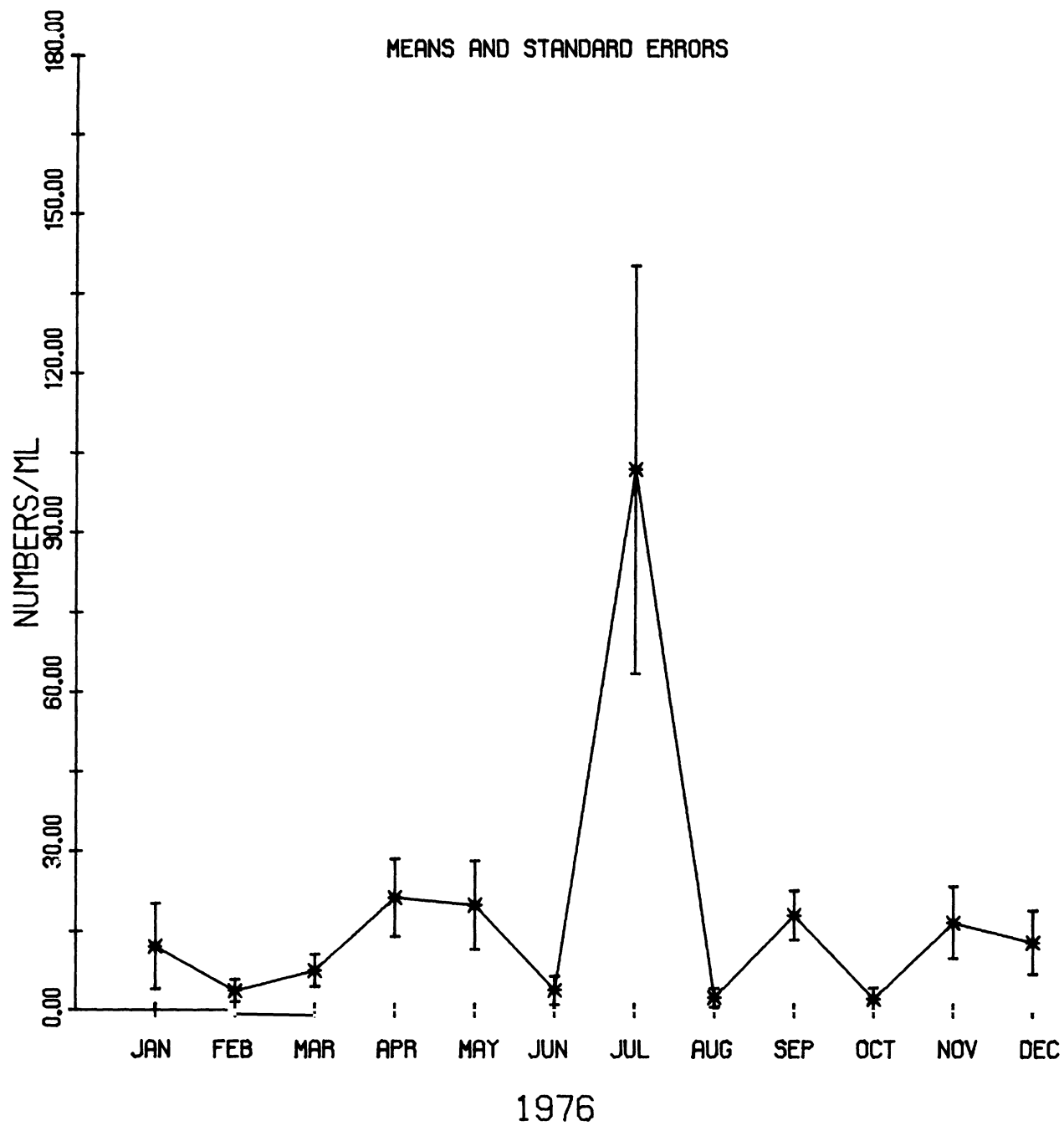


FIG. 60. Variation of Fragilaria intermedia numbers during 1976.



## FRAGILARIA INTERMEDIA

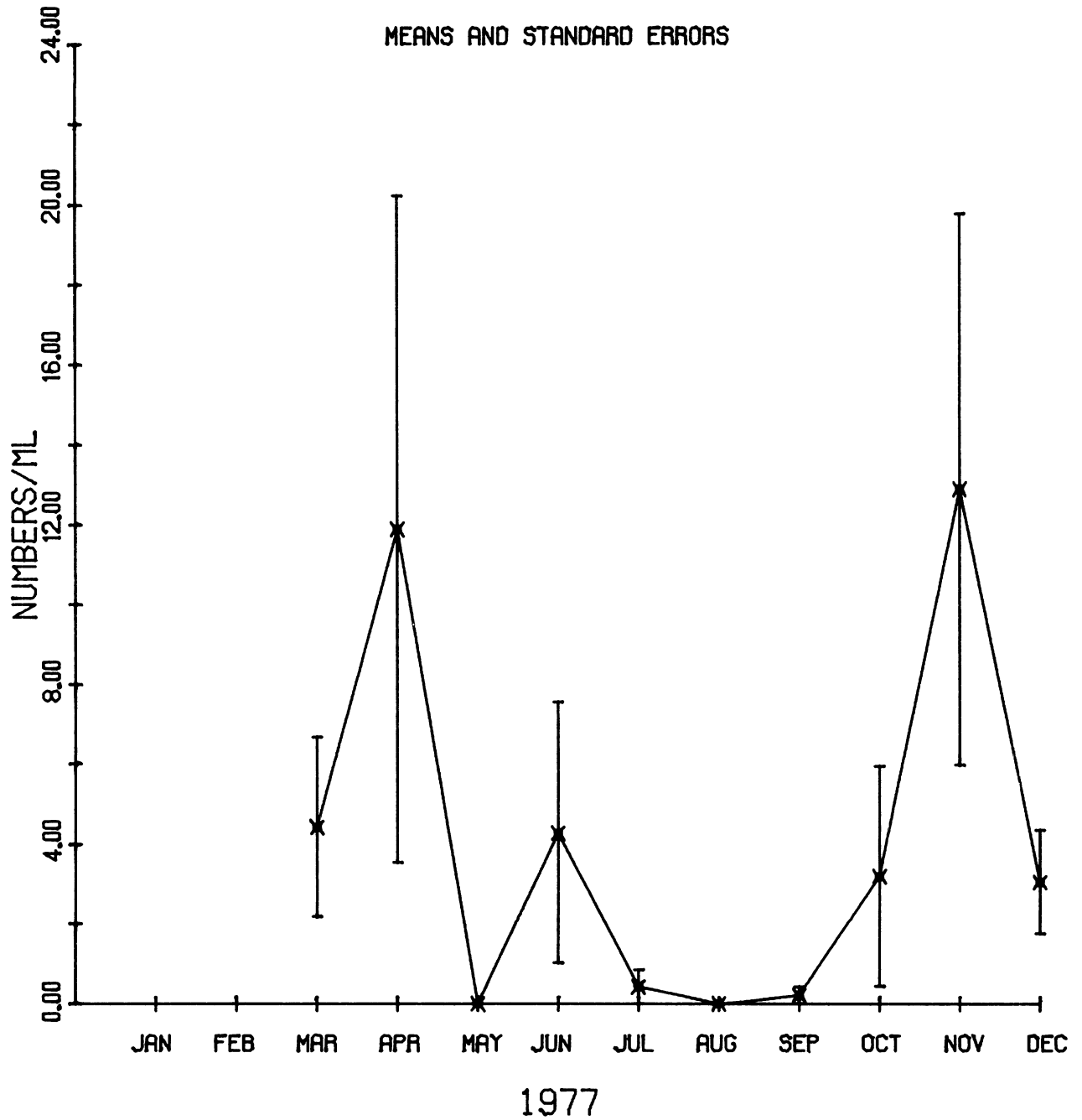


FIG. 61. Variation of Fragilaria intermedia numbers during 1977.

## FRAGILARIA INTERMEDIA V. FALLAX

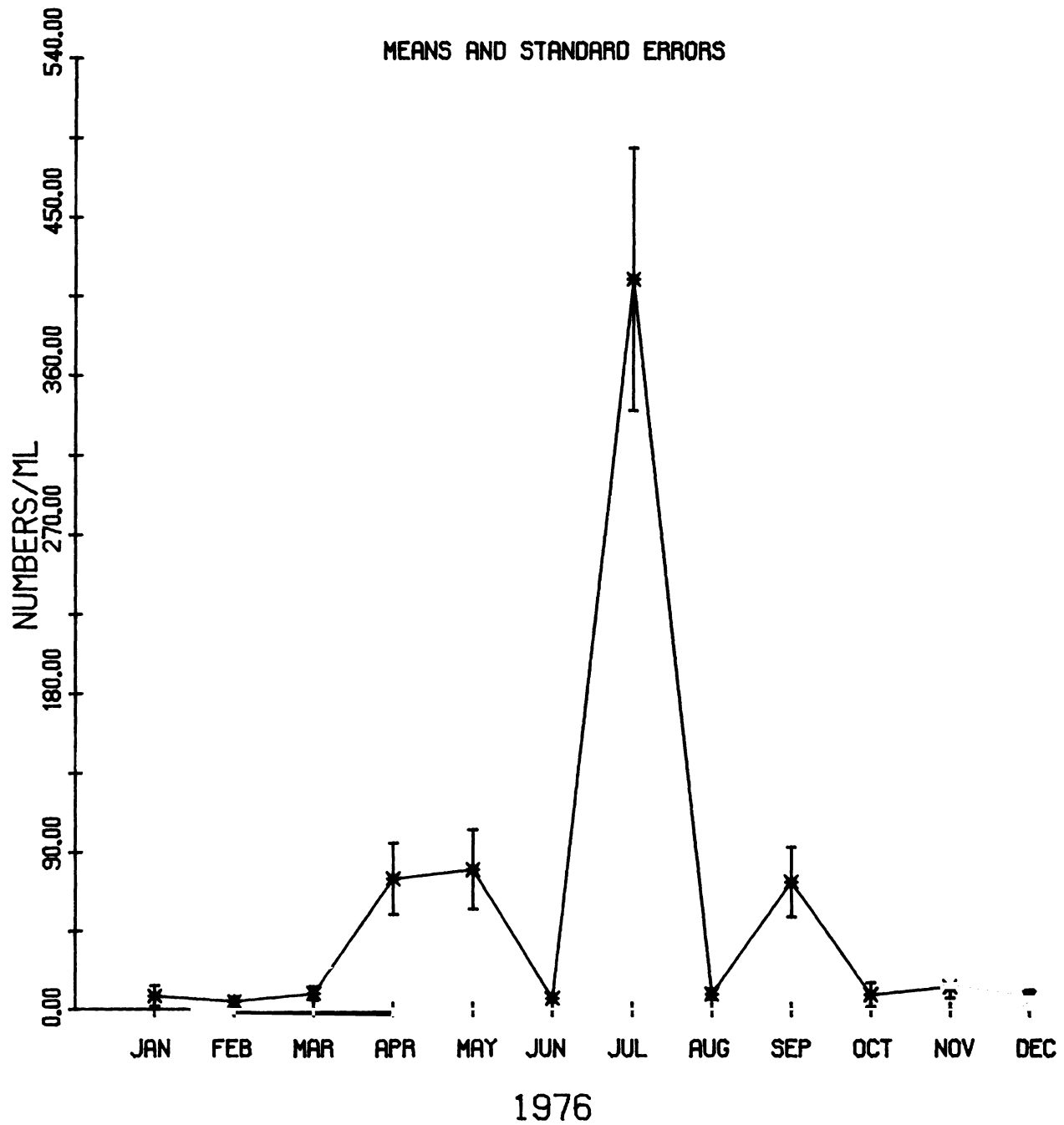


FIG. 62. Variation of Fragilaria intermedia v. fallax numbers during 1976.

## FRAGILARIA INTERMEDIA V. FALLAX

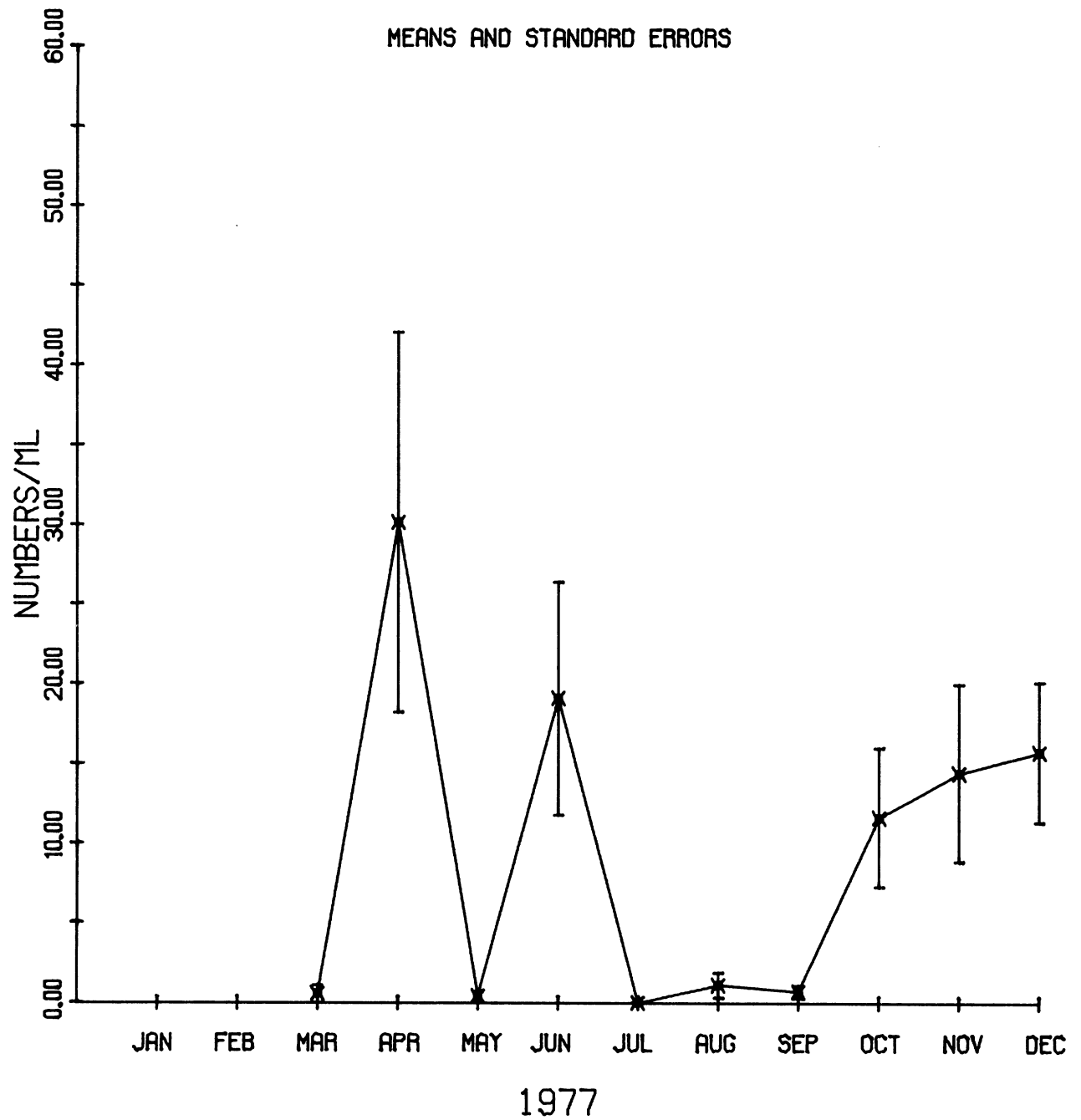


FIG. 63. Variation of Fragilaria intermedia v. fallax numbers during 1977.

# TABELLARIA FENESTRATA V. INTERMEDIA

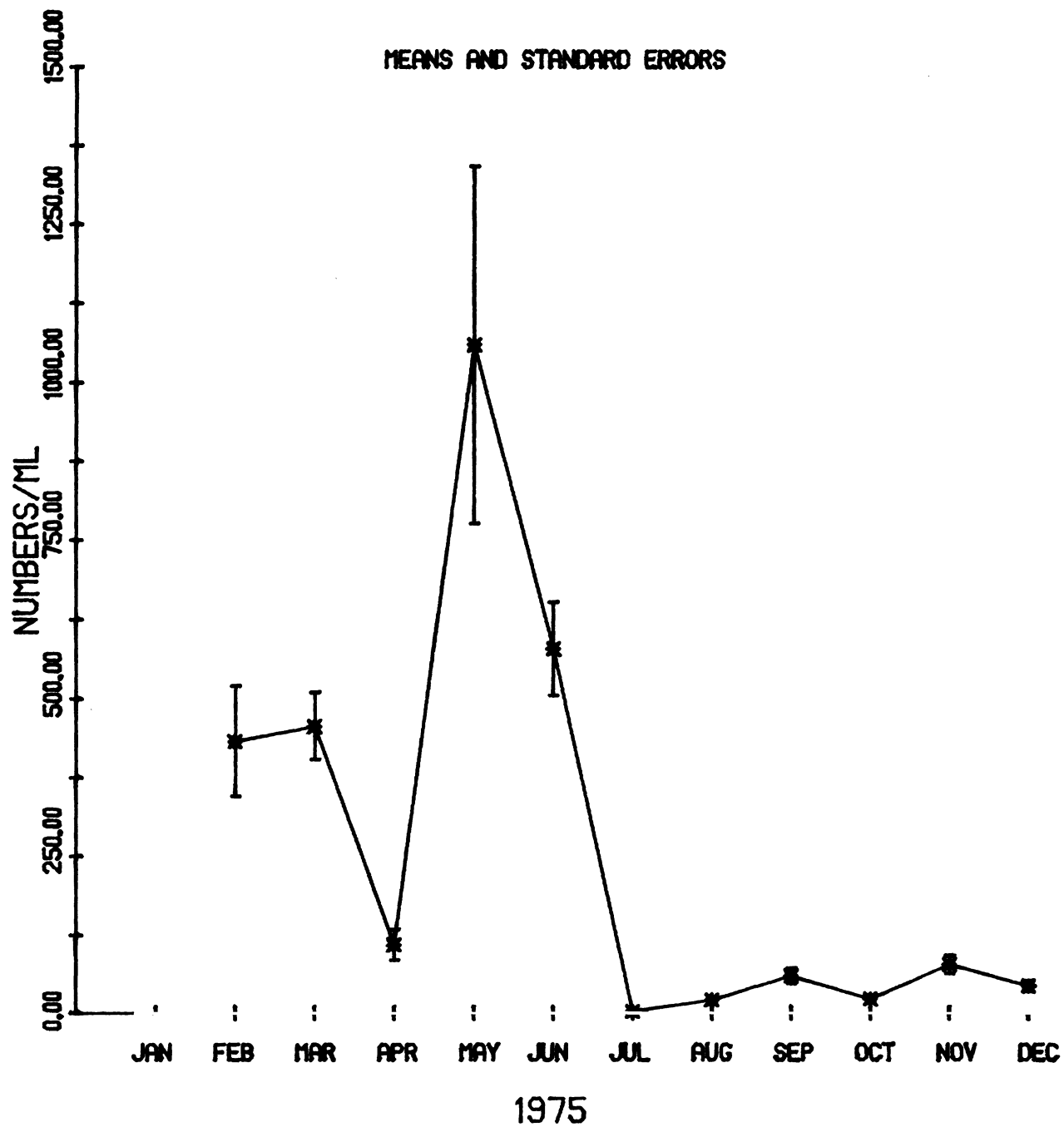


FIG. 64. Variation of Tabellaria fenestrata v. intermedia numbers during 1975.

# TABELLARIA FENESTRATA V. INTERMEDIA

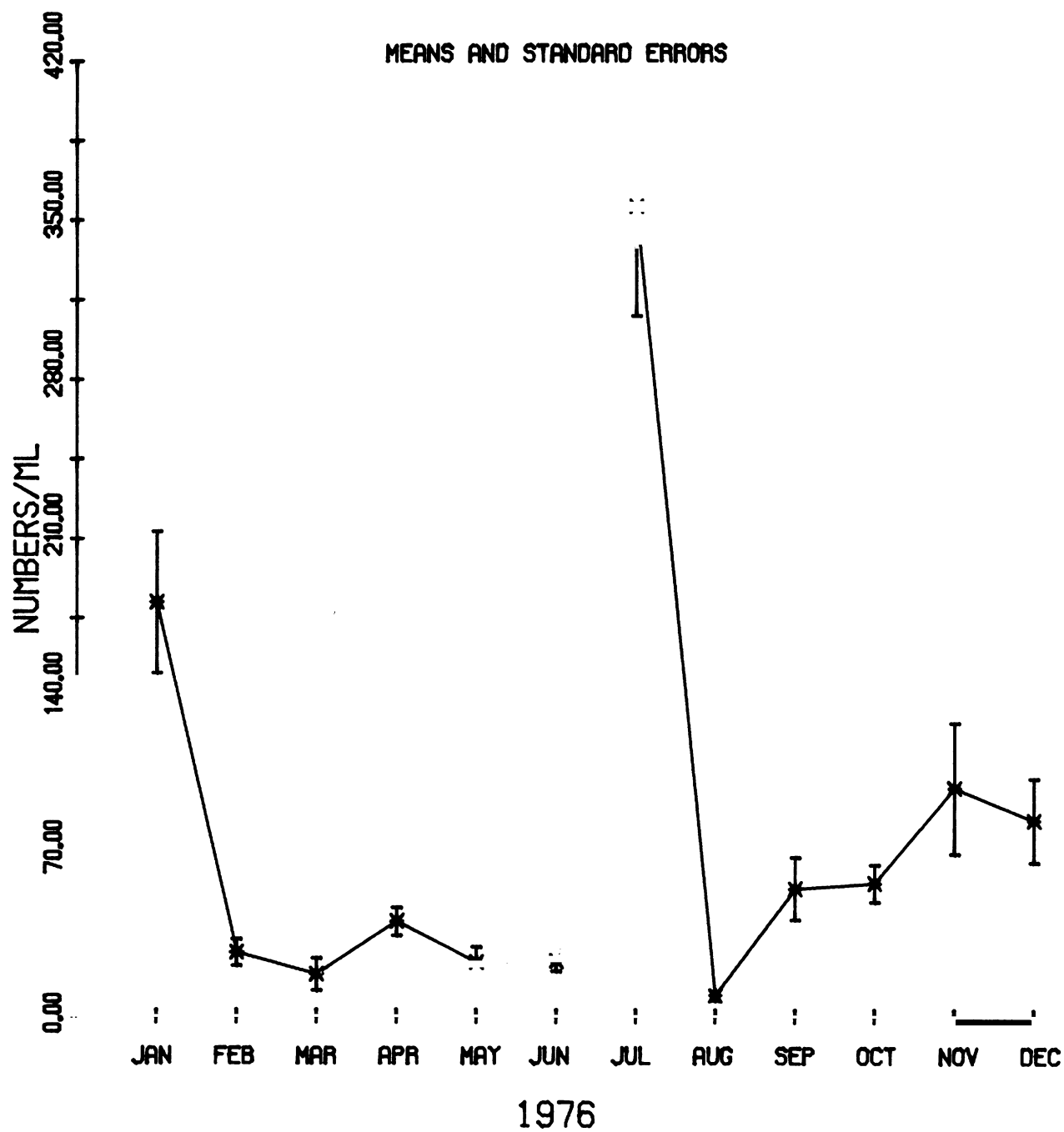


FIG. 65. Variation of *Tabellaria fenestrata* v. *intermedia* numbers during 1976.

# TABELLARIA FENESTRATA V. INTERMEDIA

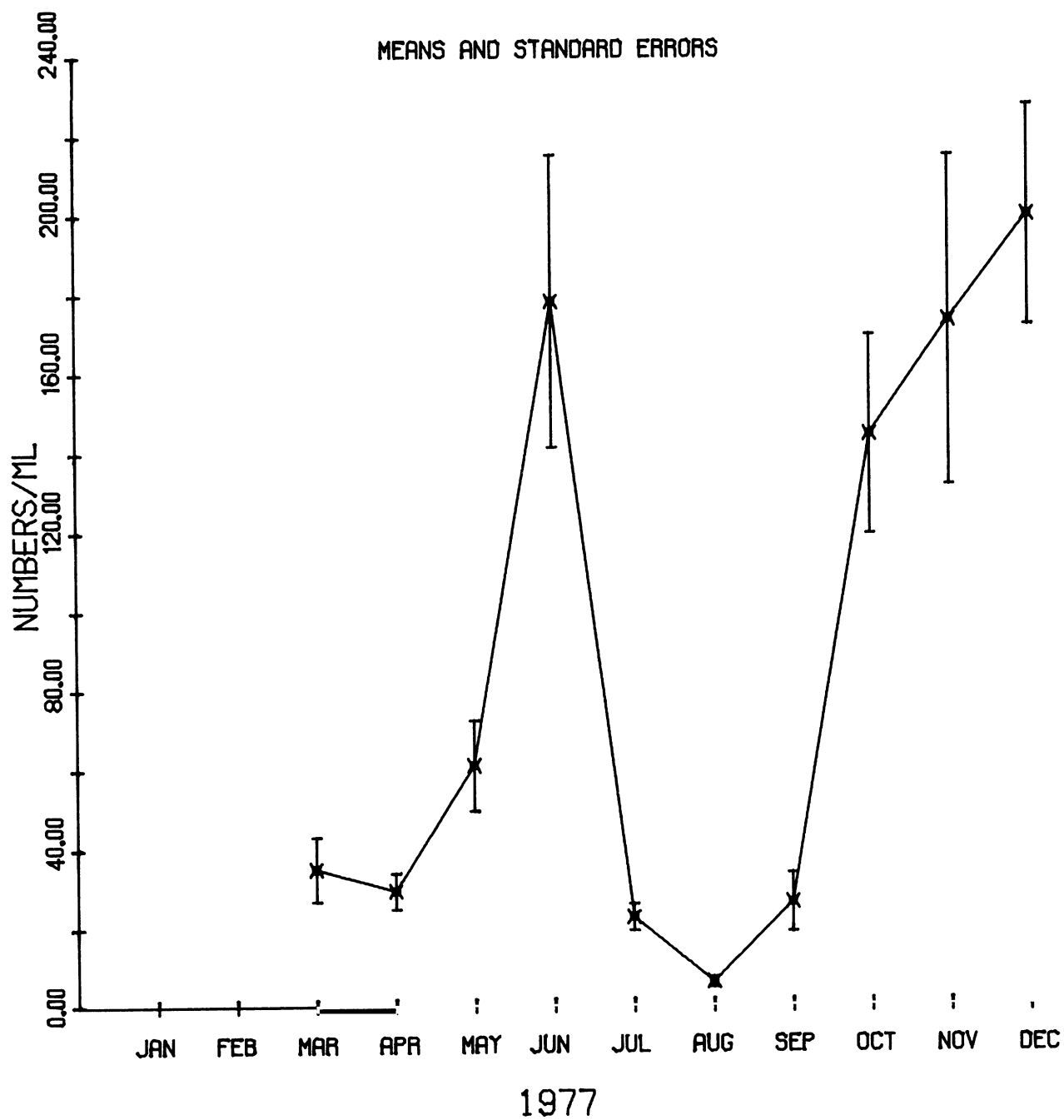


FIG. 66. Variation of *Tabellaria fenestrata* v. *intermedia* numbers during 1977.

Synedra filiformis--

Of the years in question, this species was only dominant in 1977 (Figure 67). The population was low in 1976 and increased in 1977 to a point above the 1975 level. In all 3 years, with the exception of July 1976 (period of strong upwelling), the summer months have been a period of minimal abundance. This could be due to some combination of nutrient depletion and this species' preference for lower temperatures (Stoermer and Ladewski 1976). In considering its lower temperature preference, it seems unlikely that the dominance of this species in 1977 could be due to an effect of the plant. Future data must be considered to determine if this is a fluctuation in the population or a change indicative of increasing nutrient loading in southern Lake Michigan. Synedra filiformis experiences maximum abundance in a moderately enriched mesotrophic environment (Tarapchak and Stoermer 1976).

Synedra ostenfeldii--

The behavior of this species is very similar to that of Synedra filiformis. It appeared as a dominant only in 1977 (Figure 68). In 1975 and 1976 the abundances were very low (never greater than 18 cells per mL). Since its ecological affinities are similar to those of Synedra filiformis the remarks expressed regarding Synedra filiformis are also pertinent here.

Of the changes which occurred in the phytoplankton species that were dominant in the entrainment data for 1 or more years between 1975 and 1977, only a few may possibly be attributed to an effect of the plant. Many of the species had concentrations which showed no consistent changes. The frequently

## SYNEDRA FILIFORMIS

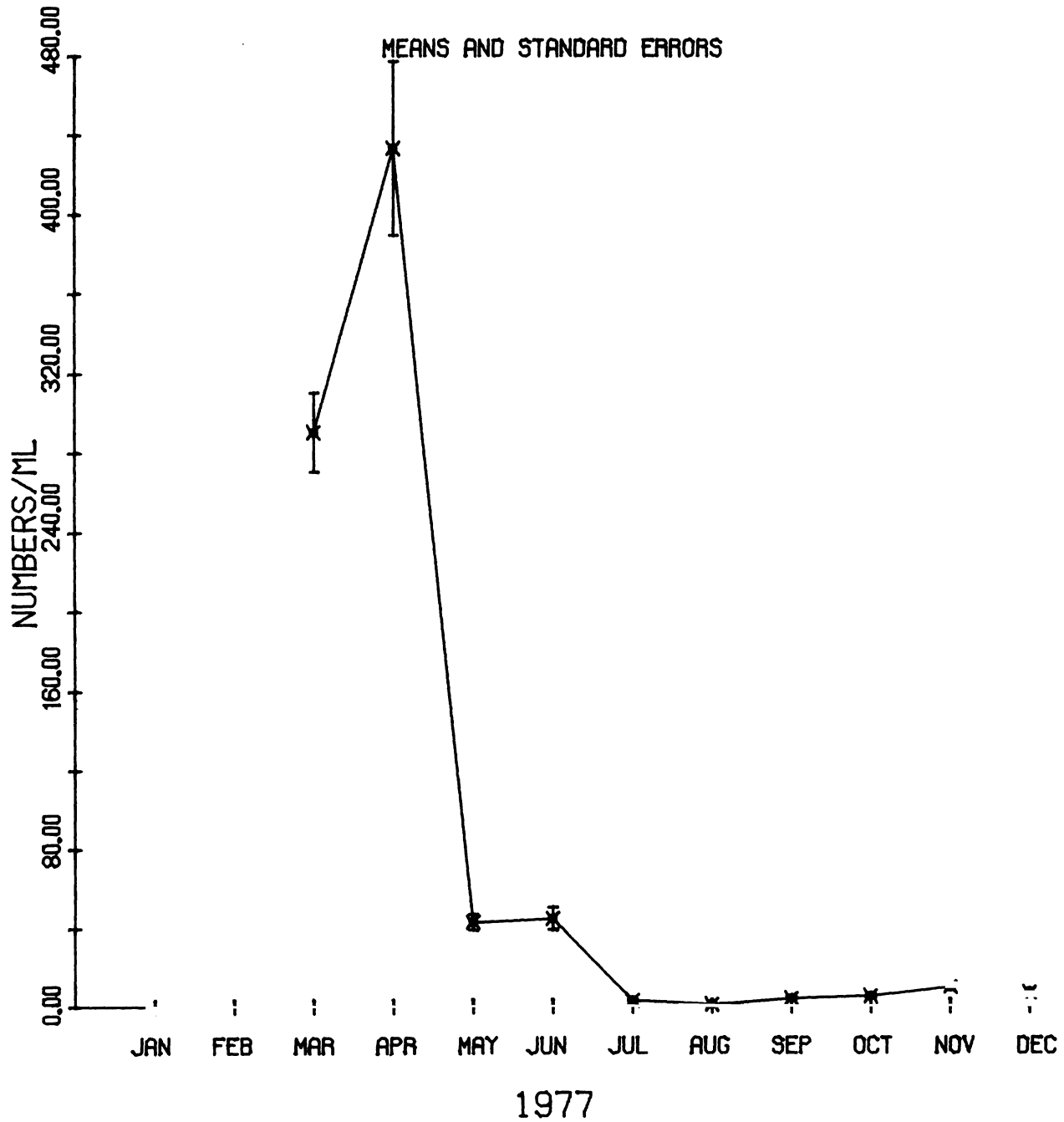


FIG. 67. Variation of Synedra filiformis numbers during 1977.



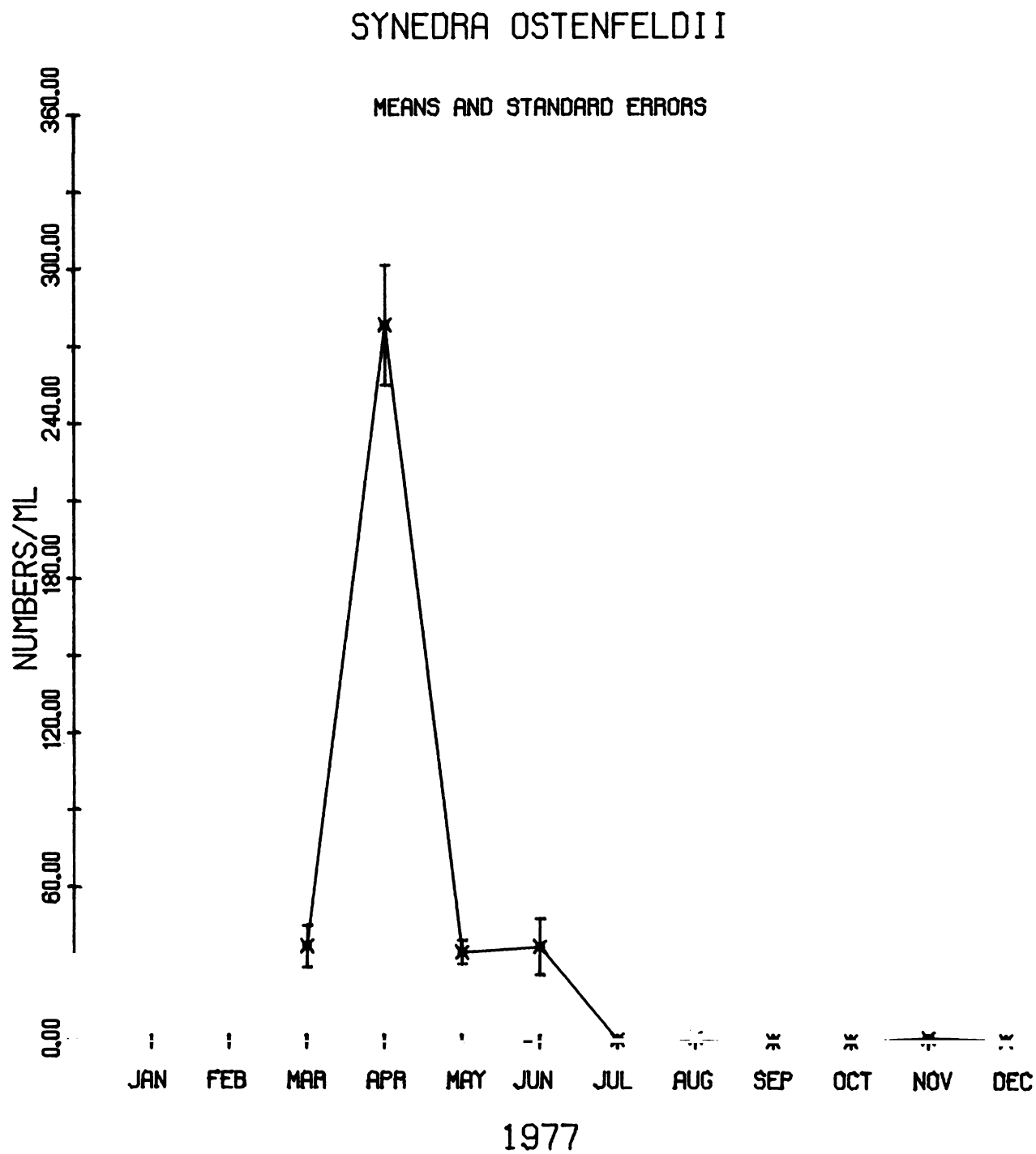


FIG. 68. Variation of Synedra ostenfeldii numbers during 1977.

large oscillations are most likely due to natural variation. In the case of many of the small colonial species, their 1- or 2-month periods of dominance (over a 3-year period) are probably the effect of their high density of cells per small colony. Some of the species were dominant only after known periods of strong upwelling. Cyclotella stelligera, Stephanodiscus tenuis, and Chromulina parvula decreased steadily in the 3-year period, while Cyclotella comensis increased. However, these changes are typical of the changes occurring in southern Lake Michigan. A number of phytoplankton species had similar occurrences in 1975 and 1976, with changes occurring in the 1977 data. In these cases, future data must be considered to determine the significance of these variations. Some of the species were found to be more frequently dominant in the entrainment samples than in those from the lake stations. One of these, Diatoma tenue v. elongatum, has an affinity for chloride-rich habitats. In order to determine the true effects of the plant on these species a close comparison of the entrainment and lake data must be carried out. In either all 3 years, or some portion thereof, several species experienced winter blooms which are not typically part of their seasonal cycles. This is most likely due to the warmer discharge water and the effects of de-icing.

#### PHYTOPLANKTON TEMPERATURE REGIMES

Temperature regimes and the temperatures of maximum abundance were calculated for the major phytoplankton species for the years 1975, 1976 and 1977 (Tables 34-36). The temperature regimes were determined by including all temperatures corresponding to months in which the number of cells were greater than or equal to ten percent of the maximum for a particular species for one year. An attempt is made to examine the similarities or differences between

TABLE 34. Temperature regimes for 1975 major phytoplankton species.

Alga	Temp. Range °C	Temp. of Max. Abundance
<u>Agmenellum quadruplicatum</u>	10-24	10, 24
<u>Anacystis incerta</u>	4-24	7, 20
<u>Anacystis thermalis</u>	22-24	20
<u>Chromulina parvula</u>	6-20	22
<u>Cyclotella comensis</u>	6-15	6
<u>Cyclotella stelligera</u>	4-24	4, 24
<u>Dictyosphaerium pulchellum</u>	23-24	24
<u>Fragilaria capucina</u>	4-11	7
<u>Fragilaria crotonensis</u>	4-20	7
<u>Fragilari intermedia</u>	2-6	3
<u>Goeocystis planctonica</u>	6-24	24
<u>Gomphosphaeria lacustris</u>	4-24	14
<u>Oscillatoria limnetica</u>	6-13	11
<u>Sphaerocystis schroeteri</u>	6-24	10
<u>Stephanodiscus tenuis</u>	2-13	4
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	4-17	7

TABLE 35. Temperature regimes for 1976 major phytoplankton species.

Alga	Temp. Range °C	Temp. of Max. Abundance
<u>Anabaena flos-aquae</u>	3-21	4
<u>Anacystis incerta</u>	2-21	-----
<u>Asterionella formosa</u>	2-16	8
<u>Cyclotella comensis</u>	2-19	7
<u>Cyclotella stelligera</u>	2-16	2
<u>Diatoma tenue</u> v. <u>elongatum</u>	2-20	15
<u>Dinobryon bavaricum</u>	20	-----
<u>Dinobryon divergens</u>	3-20	20
<u>Fragilaria crotonensis</u>	2-21	21
<u>Fragilaria intermedia</u> v. <u>fallax</u>	7-19	15
<u>Fragilaria capucina</u> v. <u>lanceolata</u>	2-21	-----
<u>Gloeocystis planctonica</u>	3-21	-----
<u>Gomphosphaeria aponina</u>	2-3	2
<u>Gomphosphaeria aponina</u> v. <u>delicatula</u>	2-3	2
<u>Gomphosphaeria lacustris</u>	2-20	-----
<u>Oscillatoria limnetica</u>	12-13	12
<u>Rhizosolenia gracilis</u>	3-20	8
<u>Stephanodiscus minutus</u>	2-16	8
<u>Stephanodiscus subtilus</u>	2-19	12,15
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	2-19	15

TABLE 36. Temperature regimes for 1977 major phytoplankton species.

Alga	Temp. Range	Temp. of Max. Abundance
<u>Agmenellum quadruplicatum</u>	4-22	4,11,15
<u>Anabaena flos-aquae</u>	4-22	20
<u>Anacystis cyanea</u>	4-20	14
<u>Anacystis incerta</u>	4-22	22
<u>Anacystis thermalis</u>	4-22	22
<u>Asterionella formosa</u>	1-22	11
<u>Cyclotella comensis</u>	1-20	20
<u>Cyclotella stelligera</u>	1-22	8
<u>Crucigenia rectangularis</u>	22	22
<u>Fragilaria crotonensis</u>	1-20	8
<u>Gomphosphaeria lacustris</u>	1-20	11
<u>Synedra filiformis</u>	1-15	8
<u>Synedra ostenfeldii</u>	1-15	8
<u>Tabellaria fenestrata</u> v. <u>intermedia</u>	1-20	4,15

these data and the data presented for previous studies (Muler 1972, Stoermer and Ladewski 1976, Talling 1955, Wasenberg-Lund 1908).

The abundance of a particular phytoplankton species is dependent on light, temperature, inorganic nutrients, organic micro-nutrients, and biological factors of competition (Wetzel 1975). This frequently makes it difficult to clearly see the effects of one variable (e.g. temperature). One result of this complicated interrelationship is the inability to assume that a species cannot exist at a specific temperature if it does not appear to do so in these data. For some species the data were either insufficient (in the literature or in our findings), or they lacked consistency, not lending themselves to any influences. These data will not be discussed here.

All of the blue-green species, Cyanophyta, which appeared as dominants between 1975 and 1977 (Agmenellum quadruplicatum, Anabaena flos-aquae, Anacystis cyanea, Anacystis incerta, Anacystis thermalis, Gomphosphaeria aponina, Gomphosphaeria aponina v. delicatula, Gomphosphaeria lacustris, and Oscillatoria limnetica) exhibited temperature ranges which were inconsistent with the literature. Some of the diatoms (Fragilaria capucina, Rhizosolenia gracilis, Fragilaria crotonensis, Stephanodiscus subtilis, and Cyclotella stelligera) as well as the chrysophyte Dinobryon divergens were also found at temperatures below those stated in previous studies (Table 37). For Anacystis thermalis, the lower temperature at which this species is commonly known to exist has been lowered from 10°C (Stoermer and Ladewski 1976) to 2°C. Several of the species exhibited peaks in abundance at these low temperatures (Anabaena flos-aquae at 4°C and Anacystis incerta at 7°C).

Three possible explanations exist for this discrepancy: 1) these algae actually exist at these lower temperatures (very unlikely); 2) the phytoplankton in the thermal plume area of the plant are somehow affected by

TABLE 37. Temperature regimes for various phytoplankton species.

Alga	Temp. Range, °C	Temp. of Max. Abund., °C
<u>Anacystis thermalis</u>	>10 <sup>1</sup>	18 <sup>1</sup>
<u>Stephanodiscus tenuis</u>		6-8 <sup>1</sup>
<u>Fragilaria capucina</u>	high temp. <sup>1</sup> (15-30) <sup>3</sup>	20 <sup>3</sup>
<u>Fragilaria crotonensis</u>	15-30 <sup>3</sup> , 8-14 <sup>5</sup> eurythermal	15 <sup>1</sup> , 7 <sup>1</sup> , (13-16) <sup>4</sup> 26 <sup>3</sup>
<u>Anabaena flos-aquae</u>	16-21 <sup>5</sup>	17 <sup>1</sup> , 17 <sup>5</sup>
<u>Diatoma tenue</u> v. <u>elongatum</u>	3-18 <sup>1</sup>	
<u>Rhizosolenia gracilis</u>	eurythermal <sup>1</sup>	15 <sup>1</sup>
<u>Fragilaria intermedia</u> v. <u>fallax</u>		4 <sup>1</sup>
<u>Oscillatoria limnetica</u>		18 <sup>1</sup>
<u>Stephanodiscus subtilis</u>	>9 <sup>1</sup>	18-19 <sup>1</sup>
<u>Gomphosphaeria lacustris</u>		16 <sup>1</sup> , 14 <sup>6</sup> , 12-18 <sup>5</sup>
<u>Gomphosphaeria aponina</u>		13 <sup>1</sup>
<u>Dinobryon divergens</u>	5-8, <sup>6</sup> fairly high temp.	18-19 <sup>1</sup> , 8 <sup>5</sup> , 12 <sup>6</sup>
<u>Asterionella formosa</u>	5-20 <sup>2</sup>	3-6 <sup>1</sup> , 17-20 <sup>2</sup> , 15-17 <sup>1</sup>
<u>Cyclotella stelligera</u>	>18 <sup>1</sup> , <8 <sup>1</sup>	
<u>Stephanodiscus minutus</u>		3 <sup>1</sup>
<u>Cyclotella comensis</u>	14-15 <sup>5</sup>	12 <sup>5</sup>
<u>Anacystis incerta</u>	high temp. <sup>1</sup>	18 <sup>1</sup>

<sup>1</sup> Stoermer and Ladewski 1976.<sup>2</sup> Talling 1955.<sup>3</sup> Muler 1972.<sup>4</sup> Wasenberg-Lund 1908.<sup>5</sup> Findenegg 1943.<sup>6</sup> Stoermer et al. 1974.

the warmer (10°C) discharge water; and 3) some algae exist in the discharge and intake pipes which are able to withstand the toxicity of chlorination and grow in water above the ambient temperature until they are dislodged and carried into the sampling area of the plant. The third explanation would be of particular significance during periods of de-icing in the winter, when the center intake pipe becomes a discharge outlet, with the discharge water being released in very close proximity to the other two intakes. At the present time data do not exist to substantiate either of these two more plausible hypotheses.

In July 1976, many species showed maximum density peaks at 15°C. The occurrences of Diatoma tenue v. elongatum, Fragilaria intermedia v. fallax, Stephanodiscus subtilis, and Tabellaria fenestrata v. intermedia were probably related to upwelling. The significance of this upwelling was a lowering of water temperature and replenishment of dissolved silica. Low dissolved silica concentrations usually terminate or greatly reduce most diatom growth at this time of the year (Wetzel 1975).

The data obtained for some of the dominant species (Asterionella formosa, Stephanodiscus minutus, and Diatoma tenue v. elongatum) were consistent with those from previous studies (Table 37).

#### CHLOROPHYLLS AND PHAEOPHYTIN a

Chlorophylls and phaeophytin a data have been used 1) to monitor monthly changes in these variables with respect to observed phytoplankton densities, 2) to determine the change in these variables that would be detectable at the .05 level of significance, 3) to assess the impact of chlorination on phytoplankton viability, 4) to assess immediate impact of entrainment on phytoplankton viability, and 5) to assess impact of entrainment on phytoplankton hours after



entrainment. When phytoplankton pass through the plant, several possible alterations of the population's viability may occur. Among these are killing or damage to the organism during periods of chlorination, destruction or inhibition from the mechanical and heat effects of passage, and stimulation of productivity due to increased temperatures.

#### Percentage of Change Detectable at the 0.05 Level of Significance

To establish the least change in each of the chlorophylls, phaeophytin a, and the phaeophytin a to chlorophyll a ratio that is detectable with 95% power by analysis of variance, the equation derived by Johnston (1974) from an equation of Sokal and Rohlf (1969, p. 247) was used. It is

$$\delta = \sigma \sqrt{\frac{2}{n}} (t_{\alpha[v]} + t_{2(1-P)[v]}) \text{ where}$$

$\delta$  = least detectable true difference

$\sigma$  = true error standard deviation

$v$  = degrees of freedom of the error mean square

$n$  = number of observations for each case

$t$  = student's  $t$

$\alpha$  = significance level

$P$  = power (the desired probability that a difference will be found significant).

For  $\alpha = 0.05$  and  $P = 0.95$ ,  $\delta$  may be calculated. The calculated  $\delta$ 's for chlorophyll a, chlorophyll b, chlorophyll c, phaeophytin a, and the phaeophytin a to chlorophyll a ratio based on 73 cases consisting of five observations each are presented in Table 38. Compared to 1975 and 1976, the 1977  $\delta$  for each variable was less (Rossmann et al. 1977, Rossmann et al. 1979). The downward

TABLE 38. Least detectable true difference for chlorophyll a, chlorophyll b, chlorophyll c, phaeophytin a, and the phaeophytin a to chlorophyll a ratio.<sup>1</sup>

Variable	Mean	True Error Standard Deviation	$\delta$
Chlorophyll <u>a</u>	4.73	0.773	1.79
Chlorophyll <u>b</u>	0.0351	0.119	0.276
Chlorophyll <u>c</u>	1.20	0.411	0.953
Phaeophytin <u>a</u>	0.578	0.470	1.09
Phaeophytin <u>a</u> / Chlorophyll <u>a</u>	0.147	0.140	0.324

<sup>1</sup> 0.95 probability that the differences will be significantly different at the 0.05 level.

trend in least detectable true difference may be attributed to the development and implementation of more a quantitative chlorophyll extraction method (Rossmann et al. 1979).

#### Grinding Versus Sonification of Samples

In the report on the 1976 entrainment data (Rossmann et al. 1979) the merits of using grinding instead of sonification for sample preparation were discussed. At that time, it was indicated that additional comparisons of two methods would be made. These additional comparisons were to be primarily directed at determining preparation differences on the amount of chlorophyll b extracted. Three such additional comparisons were made during the months of July, August, and September of 1977. Unfortunately, the green algae, the only ones containing chlorophyll b, were not nearly as abundant as in 1975. Thus, no conclusion can be made concerning the relative extraction of chlorophyll b by the two methods.

The additional results obtained from this study also contain information on the relative extractability of chlorophyll a, chlorophyll c, phaeophytin a, and the phaeophytin a/chlorophyll a ratios. These are presented here. During this period of collection, neither of the chlorophylls nor the phaeophytin a were particularly high. Thus, differences between the two extraction methods are not as dramatic as presented previously. Tables 39 through 43 contain the results. In July, the ground samples had significantly ( $P \leq 0.01$ ) higher concentrations of chlorophyll a and phaeophytin a and a significantly lower phaeophytin a/chlorophyll a ratio. In August, the ground samples had a significantly higher chlorophyll c, phaeophytin a, and phaeophytin a/chlorophyll a ratio. The latter two are believed to originate from working

TABLE 39. COMPARISON OF PRE-EXTRACTION TECHNIQUES FOR CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE.

DATE	TIME INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
7/12/77	GROUND	5	0.223E+01	0.131E+00			
7/12/77	SONIFIED	5	0.187E+01	0.894E-01	GROUND VS. SONIFIED	0.512E+01	0.537E-01
8/09/77	GROUND	4	0.182E+01	0.111E+00			
8/09/77	SONIFIED	5	0.189E+01	0.138E+00	GROUND VS. SONIFIED	0.954E-01	0.757E+00
9/13/77	GROUND	5	0.266E+01	0.125E+00			
9/13/77	SONIFIED	4	0.263E+01	0.179E+00	GROUND VS. SONIFIED	0.169E-01	0.887E+00

TABLE 40. COMPARISON OF PRE-EXTRACTION TECHNIQUES FOR CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE.

DATE	TIME INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
7/12/77	GROUND	5	0.0	0.0			
7/12/77	SONIFIED	5	0.430E-02	0.430E-02	GROUND VS. SONIFIED	0.100E+01	0.348E+00
8/09/77	GROUND	4	0.244E-01	0.244E-01			
8/09/77	SONIFIED	5	0.180E+00	0.171E+00	GROUND VS. SONIFIED	0.633E+00	0.456E+00
9/13/77	GROUND	5	0.0	0.0			
9/13/77	SONIFIED	4	0.470E-01	0.470E-01	GROUND VS. SONIFIED	0.130E+01	0.293E+00

TABLE 41. COMPARISON OF PRE-EXTRACTION TECHNIQUES FOR CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE.

DATE	TIME INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
7/12/77	GROUND	5	0.427E+00	0.874E-01			
7/12/77	SONIFIED	5	0.290E+00	0.120E+00	GROUND VS. SONIFIED	0.844E+00	0.389E+00
8/09/77	GROUND	4	0.285E+00	0.107E+00			
8/09/77	SONIFIED	5	0.180E-01	0.130E-01	GROUND VS. SONIFIED	0.766E+01	0.285E-01
9/13/77	GROUND	5	0.562E+00	0.470E-01			
9/13/77	SONIFIED	4	0.663E+00	0.253E+00	GROUND VS. SONIFIED	0.198E+00	0.668E+00

TABLE 42. COMPARISON OF PRE-EXTRACTION TECHNIQUES FOR PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE.

DATE	TIME INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
7/12/77	GROUND	5	0.136E+00	0.851E-01			
7/12/77	SONIFIED	5	0.429E+00	0.909E-01	GROUND VS. SONIFIED	0.557E+01	0.463E-01
8/09/77	GROUND	4	0.167E+00	0.631E-01			
8/09/77	SONIFIED	5	0.0	0.0	GROUND VS. SONIFIED	0.909E+01	0.204E-01
9/13/77	GROUND	5	0.109E+00	0.602E-01			
9/13/77	SONIFIED	4	0.980E-01	0.980E-01	GROUND VS. SONIFIED	0.977E-02	0.911E+00

TABLE 43. COMPARISON OF PRE-EXTRACTION TECHNIQUES FOR THE PHAEOPHYTIN A TO CHLOROPHYLL A RATIO USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE.

DATE	TIME INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	F-STATISTIC	SIGNIFICANCE
7/12/77	GROUND	5	0.700E-01	0.439E-01	GROUND VS. SONIFIED	0.541E+01	0.487E-01
7/12/77	SONIFIED	5	0.238E+00	0.575E-01			
8/09/77	GROUND	4	0.958E-01	0.351E-01	GROUND VS. SONIFIED	0.964E+01	0.181E-01
8/09/77	SONIFIED	5	0.0	0.0			
9/13/77	GROUND	5	0.441E-01	0.257E-01	GROUND VS. SONIFIED	0.527E-04	0.982E+00
9/13/77	SONIFIED	4	0.438E-01	0.437E-01			

near the limit of detectability. For September, no significant differences were found. Although not as conclusive or dramatic as results previously presented, the grinding method continues to be the best method of sample preparation.

#### Variations of the Chlorophylls and Phaeophytin a during Chlorination

Twenty samples were collected from the discharge forebay prior to, during, and after chlorination on May 18, 1977. Samples were collected two at a time every 5 minutes beginning at 0755 EST and ending at 0840 EST. One of these samples was incubated for 3 hours at ambient lake temperature before filtering and freezing. Results are graphically summarized in Figures 69 through 72. Chlorophyll b concentrations were too low to provide any reliable results. The 0840 EST incubated sample was lost during analysis.

No impact on fresh samples was observable for the time period considered. Though not significant (0.05 level of significance), noticeable changes occurred in the incubated samples. Beginning at 0820 and ending at 0825 or perhaps 0830, chlorophyll a was lower, chlorophyll c was lower, phaeophytin a was higher, and the phaeophytin a/chlorophyll a ratio was higher in the incubated samples than in the non-incubated samples. Thus, the phytoplankton appeared to be altered in the incubated samples. The damage illustrated here may not be as severe as presented or may not exist at all in the actual discharge water. Samples were incubated in the chlorinated water for 3 hours with no dilution. Water discharged to the lake would be diluted by ambient lake water. Thus, duration of exposure would be shorter, and the concentration of chlorine would be lower.

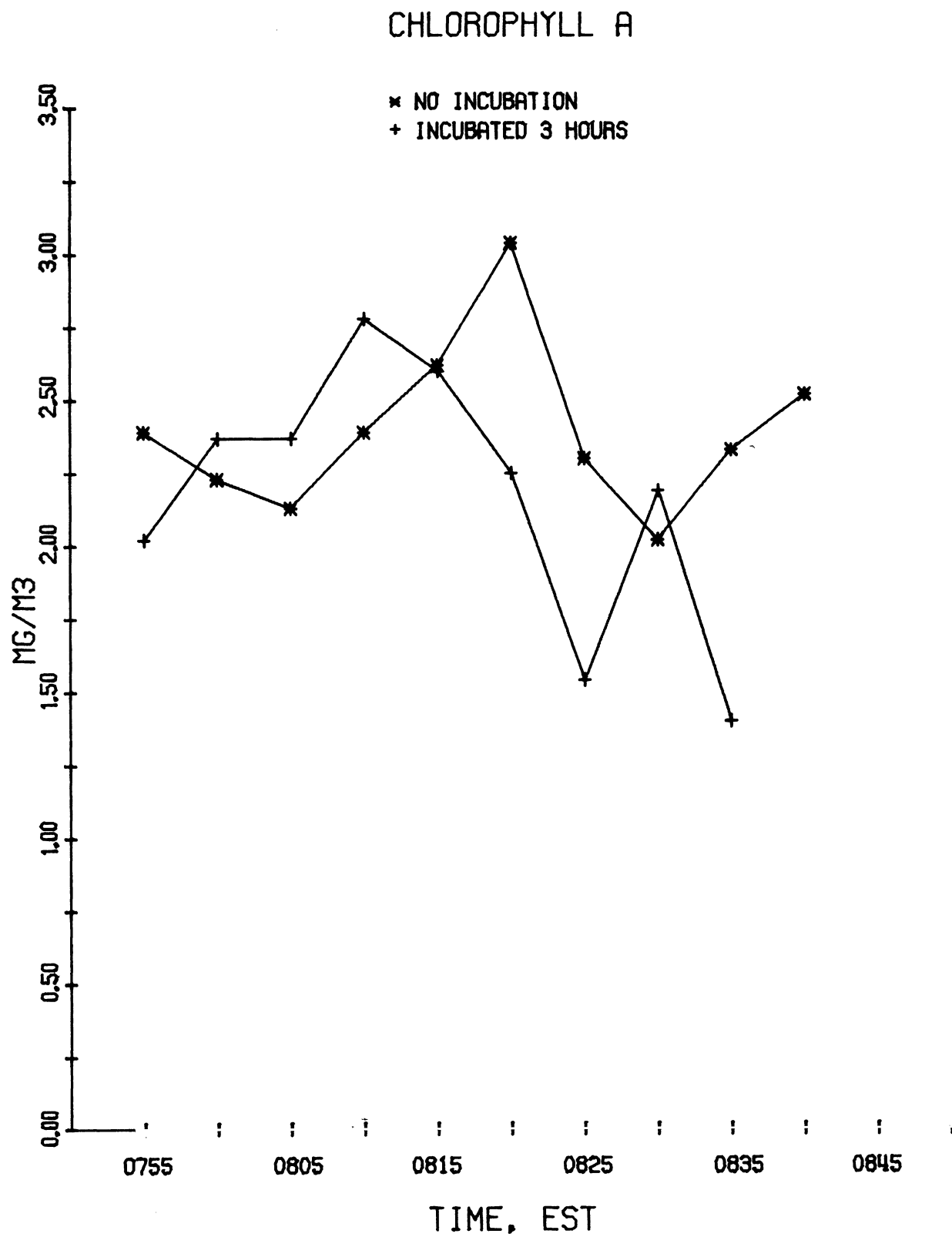


FIG. 69. Variation of chlorophyll a during a period of chlorination.



## CHLOROPHYLL C

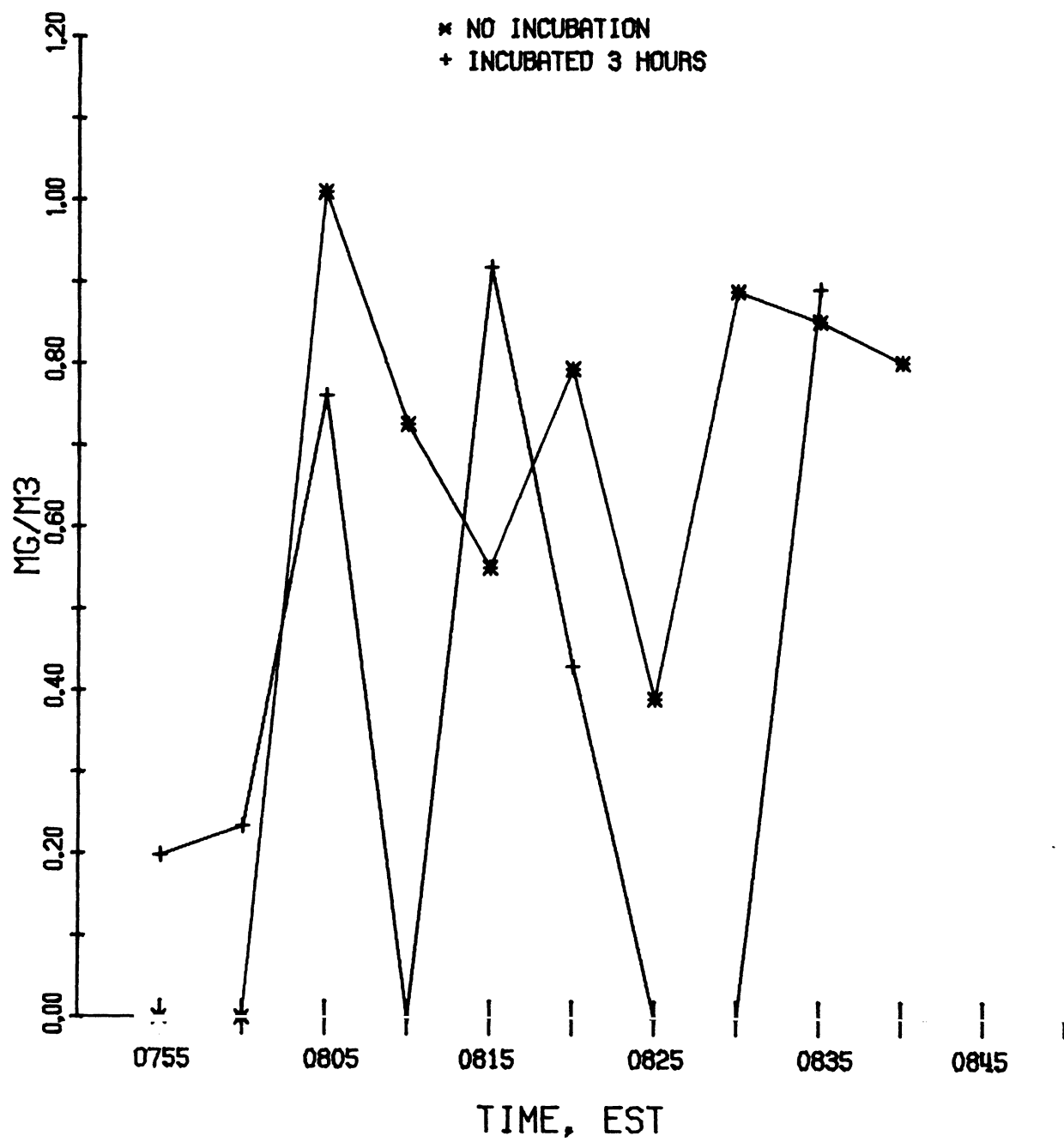


FIG. 70. Variation of chlorophyll c during a period of chlorination.

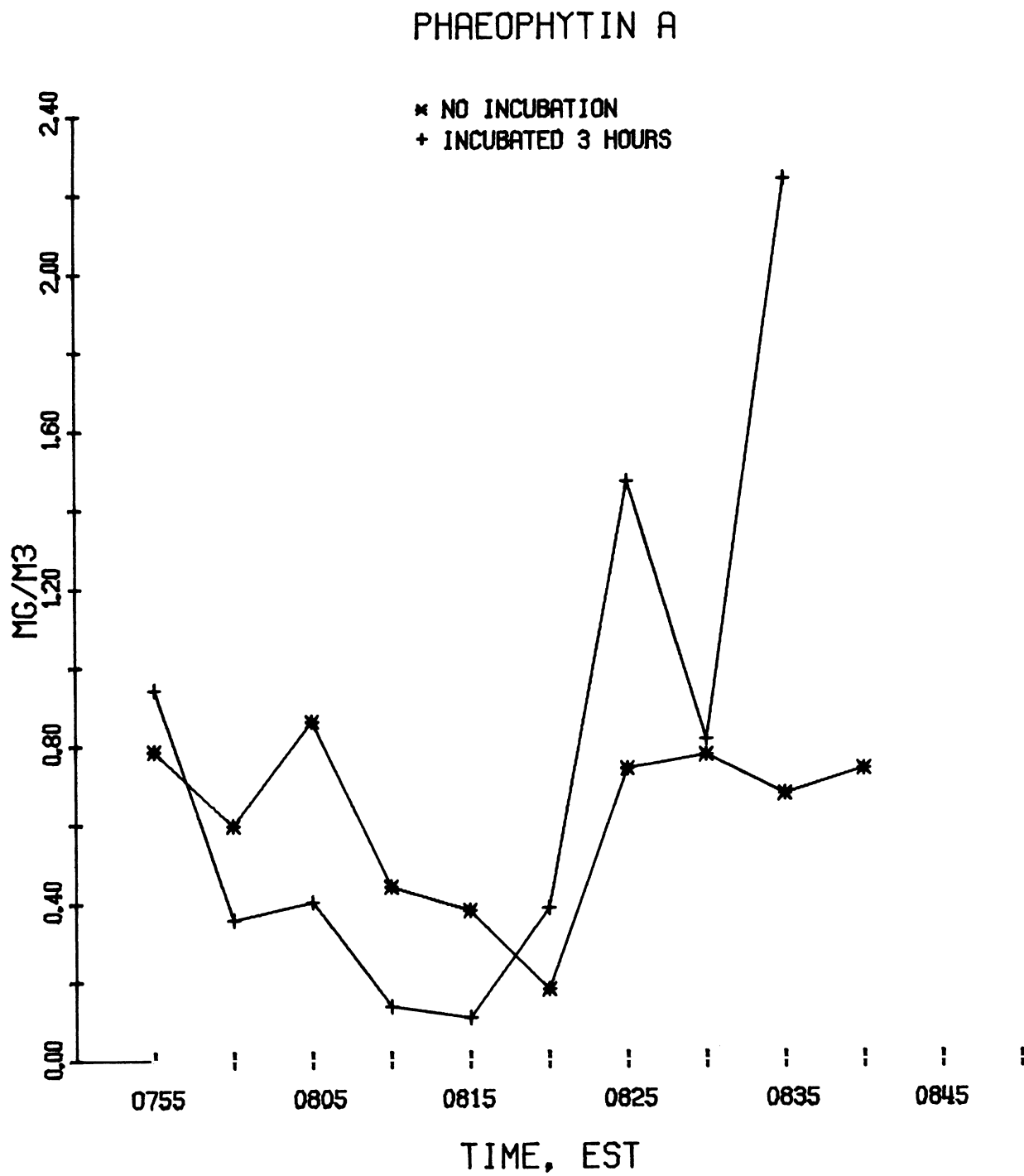


FIG. 71. Variation of phaeophytin a during a period of chlorination.

# PHAEOPHYTIN A / CHLOROPHYLL A

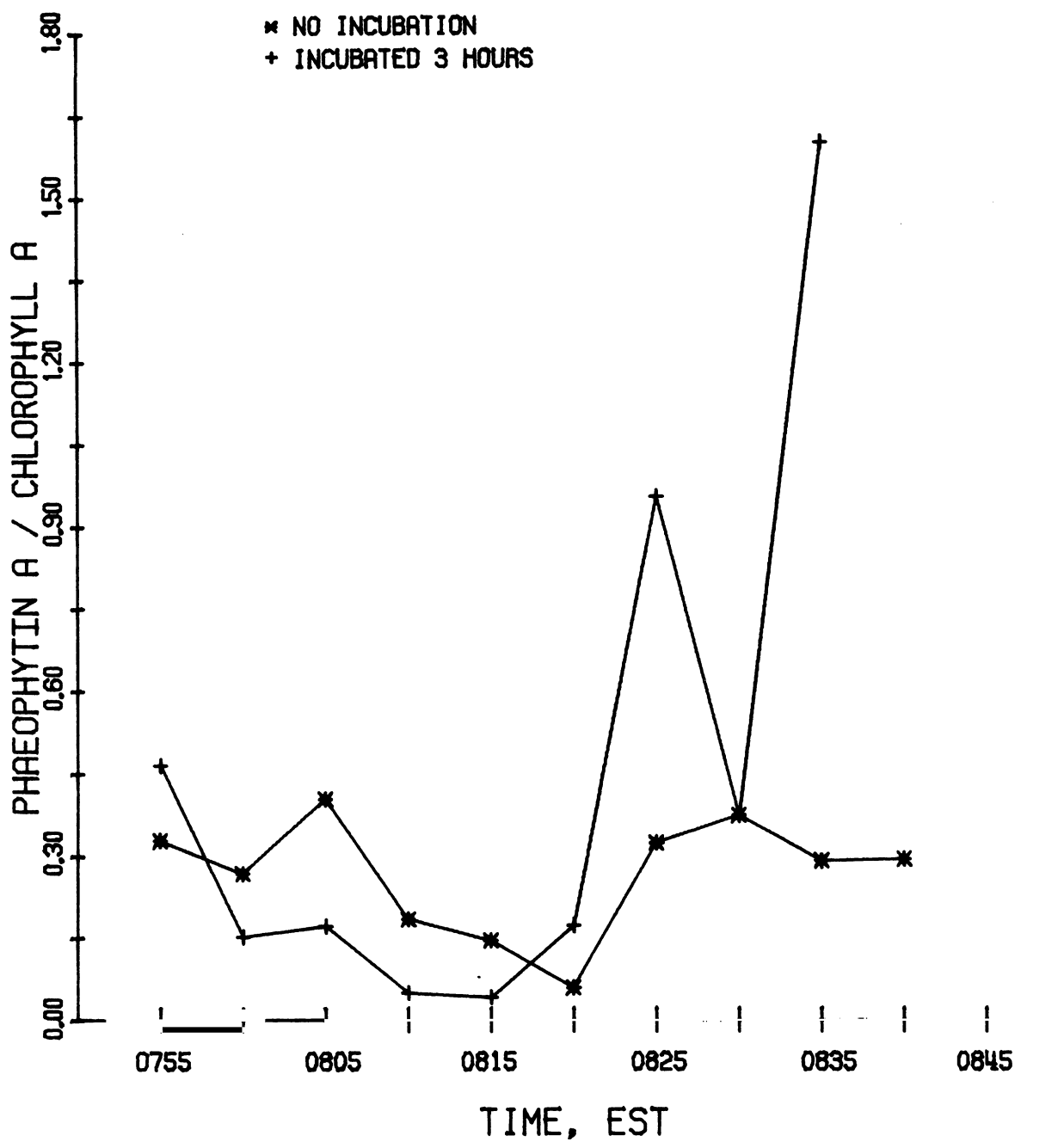


FIG. 72. Variation of the phaeophytin a/chlorophyll a ratio during a period of chlorination.

## Assessment of Damage to Phytoplankton

Results of monthly sampling for chlorophyll analyses are found in Tables 44 through 48. Because the phaeophytin a/chlorophyll a ratio is relatively insensitive to changes in viability, all chlorophyll data will be presented as in the reports on the 1975 and 1976 data (Rossmann et al. 1977, Rossmann et al. 1979). Chlorophyll a is the most sensitive of all the variables for detecting any change in viability.

Unlike 1975 and 1976, large and frequent decreases in phytoplankton viability occurred during 1977. Chlorophyll a decreased in 26% of all samples and in 60% of the incubated samples (Table 44). The average decrease in concentration was 26% and 25% for these two sample sets, respectively. Chlorophyll b increased 2.4% in concentration in less than 1% of all samples and decreased in none of them (Table 45). Chlorophyll c decreased 28% in concentration in 15% of all samples and decreased 23% in concentration in 20% of the incubated samples (Table 46). Phaeophytin a increased 298% in concentration in 15% of all samples and increased 253% in concentration in 30% of the incubated samples (Table 47). The phaeophytin a/chlorophyll a ratio increased 358% in 12% of all samples and increased 278% in 20% of the incubated samples (Table 48).

During 1977, significant decreases in viability occurred in 32 of 205 comparisons or roughly 16% of the comparisons. This is high compared with 1975 (3.6%) and 1976 (5%). Increases in viability occurred in only 1 of 205 comparisons or less than 1% of all comparisons. This is low compared to 1975 with 1.8% and 1976 with 3.8%. For the three years reported, a general rise in the occurrence of decreased viability took place. During 1977, a relatively high rate of viability decrease was noted relative to the other years. The

TABLE 44. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
03/07/77	2053 I5	0	0.489E+01	0.180E+00			
03/07/77	2102 D1	0	0.441E+01	0.130E+00	INTAKE VS. DISCHARGE	0.460E+01	0.644E-01
03/07/77	2053 I5	36	0.541E+01	0.108E+00			
03/07/77	2102 D1	36	0.693E+01	0.657E+00	INTAKE V. DISCHARGE	0.519E+01	0.524E-01
03/08/77	0536 I5	0	0.473E+01	0.629E-01			
03/08/77	0544 D1	0	0.434E+01	0.697E-01	INTAKE VS. DISCHARGE	0.164E+02	0.580E-02
03/08/77	1248 I5	0	0.930E+01	0.337E+00			
03/09/77	1255 D1	0	0.584E+01	0.316E+00	INTAKE VS. DISCHARGE	0.535E+02	0.465E-03
04/11/77	2105 I5	0	0.105E+02	0.811E+00			
04/11/77	2115 D1	0	0.832E+01	0.752E+00	INTAKE VS. DISCHARGE	0.395E+01	0.821E-01
04/11/77	2105 I5	39	0.149E+02	0.136E+01			
04/11/77	2115 D1	39	0.998E+01	0.303E+00	INTAKE VS. DISCHARGE	0.161E+02	0.602E-02
04/12/77	0434 I5	0	0.101E+02	0.467E+00			
04/12/77	0443 D1	0	0.813E+01	0.102E+00	INTAKE VS. DISCHARGE	0.172E+02	0.400E-02
04/12/77	1220 I5	0	0.687E+01	0.352E+00			
04/12/77	1235 D1	0	0.705E+01	0.616E+00	INTAKE VS. DISCHARGE	0.530E-01	0.812E+00
05/16/77	2245 I5	0	0.199E+01	0.109E+00			
05/16/77	2245 D1	0	0.164E+01	0.648E-01	INTAKE VS. DISCHARGE	0.800E+01	0.228E-01
05/16/77	2245 I5	36	0.173E+01	0.160E+00			
05/16/77	2245 D1	36	0.169E+01	0.161E+00	INTAKE VS. DISCHARGE	0.409E-01	0.832E+00
05/17/77	0434 I5	0	0.222E+01	0.650E-01			
05/17/77	0443 D1	0	0.212E+01	0.133E+00	INTAKE VS. DISCHARGE	0.419E+00	0.539E+00
05/17/77	1220 I5	0	0.375E+01	0.155E+00			
05/17/77	1235 D1	0	0.287E+01	0.367E-01	INTAKE VS. DISCHARGE	0.309E+02	0.978E-03
06/13/77	0045 I5	0	0.542E+01	0.179E+00			
06/13/77	0027 D1	0	0.402E+01	0.258E+00	INTAKE VS. DISCHARGE	0.213E+02	0.325E-02
06/13/77	0045 I5	35	0.497E+01	0.144E+00			
06/13/77	0027 D1	35	0.431E+01	0.136E+00	INTAKE VS. DISCHARGE	0.110E+02	0.115E-01
06/14/77	0325 I5	0	0.490E+01	0.267E+00			
06/14/77	0315 D1	0	0.425E+01	0.464E+00	INTAKE VS. DISCHARGE	0.148E+01	0.259E+00
06/14/77	1250 I5	0	0.376E+01	0.161E+00			
06/14/77	1235 D1	0	0.342E+01	0.163E+00	INTAKE VS. DISCHARGE	0.220E+01	0.176E+00

TABLE 44. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF SPANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON	RPTWEN	P-STATISTIC	SIGNIFICANCE
07/11/77	2335	I5	0	0.325E+01	0.127E+00	INTAKE VS.	DISCHARGE	0.391E+02	0.564E-03
07/11/77	2346	D1	0	0.237E+01	0.594E-01	INTAKE VS.	DISCHARGE	0.187E+02	0.324E-02
07/11/77	2335	I5	33	0.345E+01	0.198E+00	INTAKE VS.	DISCHARGE	0.703E+00	0.433E+00
07/11/77	2346	D1	33	0.249E+01	0.100E+00	INTAKE VS.	DISCHARGE	0.667E+01	0.330E-01
07/12/77	0423	I5	0	0.271E+01	0.111E+00	INTAKE VS.	DISCHARGE	0.254E+01	0.149E+00
07/12/77	0433	D1	0	0.249E+01	0.259E+00	INTAKE VS.	DISCHARGE	0.740E-01	0.784E+00
07/12/77	1428	I5	0	0.223E+01	0.131E+00	INTAKE VS.	DISCHARGE	0.724E-03	0.968E+00
07/12/77	1440	D1	0	0.184E+01	0.728E-01	INTAKE VS.	DISCHARGE	0.613E+01	0.387E-01
08/08/77	2210	I5	0	0.198E+01	0.214E+00	INTAKE VS.	DISCHARGE	0.776E-01	0.777E+00
08/08/77	2200	D1	0	0.156E+01	0.159E+00	INTAKE VS.	DISCHARGE	0.637E-01	0.795E+00
08/08/77	2210	I5	37	0.154E+01	0.468E-01	INTAKE VS.	DISCHARGE	0.922E+01	0.169E-01
08/08/77	2200	D1	37	0.156E+01	0.300E-01	INTAKE VS.	DISCHARGE	0.263E+01	0.143E+00
08/09/77	0415	I5	0	0.169E+01	0.105E+00	INTAKE VS.	DISCHARGE	0.200E+00	0.865E-01
08/09/77	0423	D1	0	0.169E+01	0.105E+00	INTAKE VS.	DISCHARGE	0.347E+01	0.105E+00
08/09/77	1250	I5	0	0.182E+01	0.111E+00	INTAKE VS.	DISCHARGE	0.135E+01	0.279E+00
08/09/77	1305	D1	0	0.145E+01	0.155E+00	INTAKE VS.	DISCHARGE	0.613E+01	0.387E-01
09/12/77	2036	I5	0	0.244E+01	0.237E+00	INTAKE VS.	DISCHARGE	0.776E-01	0.777E+00
09/12/77	2055	D1	0	0.217E+01	0.271E-01	INTAKE VS.	DISCHARGE	0.637E-01	0.795E+00
09/12/77	2036	I5	35	0.177E+01	0.797E-01	INTAKE VS.	DISCHARGE	0.447E+01	0.676E-01
09/12/77	2055	D1	35	0.130E+01	0.174E+00	INTAKE VS.	DISCHARGE	0.922E+01	0.169E-01
09/13/77	0539	I5	0	0.254E+01	0.626E-01	INTAKE VS.	DISCHARGE	0.263E+01	0.143E+00
09/13/77	0525	D1	0	0.257E+01	0.105E+00	INTAKE VS.	DISCHARGE	0.200E+00	0.865E-01
09/13/77	1200	I5	0	0.266E+01	0.125E+00	INTAKE VS.	DISCHARGE	0.347E+01	0.105E+00
09/13/77	1220	D1	0	0.276E+01	0.376E+00	INTAKE VS.	DISCHARGE	0.637E-01	0.795E+00
10/10/77	2117	I5	0	0.530E+01	0.223E+00	INTAKE VS.	DISCHARGE	0.447E+01	0.676E-01
10/10/77	2104	D1	0	0.464E+01	0.219E+00	INTAKE VS.	DISCHARGE	0.922E+01	0.169E-01
10/10/77	2117	I5	38	0.572E+01	0.201E+00	INTAKE VS.	DISCHARGE	0.263E+01	0.143E+00
10/10/77	2104	D1	38	0.488E+01	0.191E+00	INTAKE VS.	DISCHARGE	0.200E+00	0.865E-01
10/11/77	0658	I5	0	0.551E+01	0.181E+00	INTAKE VS.	DISCHARGE	0.347E+01	0.105E+00
10/11/77	0651	D1	0	0.511E+01	0.169E+00	INTAKE VS.	DISCHARGE	0.637E-01	0.795E+00
10/11/77	1408	I5	0	0.609E+01	0.200E+00	INTAKE VS.	DISCHARGE	0.263E+01	0.143E+00
10/11/77	1321	D1	0	0.561E+01	0.136E+00	INTAKE VS.	DISCHARGE	0.381E+01	0.865E-01

TABLE 44. MEAN CHLOROPHYLL A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
11/07/77	1927	I5	0	0.736E+01	0.523E+00			
11/07/77	1910	D1	0	0.615E+01	0.204E+00	INTAKE VS. DISCHARGE	0.461E+01	0.642E-01
11/07/77	1927	I5	37	0.848E+01	0.124E+00			
11/07/77	1910	D1	37	0.547E+01	0.616E+00	INTAKE VS. DISCHARGE	0.230E+02	0.197E-02
11/08/77	0659	I5	0	0.670E+01	0.459E+00			
11/08/77	0650	D1	0	0.573E+01	0.437E+00	INTAKE VS. DISCHARGE	0.234E+01	0.164E+00
11/08/77	1211	I5	0	0.626E+01	0.148E+00			
11/08/77	1148	D1	0	0.504E+01	0.182E+00	INTAKE VS. DISCHARGE	0.267E+02	0.138E-02
12/12/77	1355	I5	0	0.700E+01	0.134E+00			
12/12/77	1355	D1	0	0.667E+01	0.139E+00	INTAKE VS. DISCHARGE	0.294E+01	0.125E+00
12/12/77	1840	I5	02	0.602E+01	0.271E+00			
12/12/77	1840	D1	02	0.608E+01	0.200E+00	INTAKE VS. DISCHARGE	0.318E-01	0.849E+00
12/12/77	1840	I5	22	0.754E+01	0.339E+00			
12/12/77	1840	D1	22	0.691E+01	0.162E+00	INTAKE VS. DISCHARGE	0.280E+01	0.133E+00
12/12/77	1928	I5	0	0.653E+01	0.189E+00			
12/12/77	1940	D1	0	0.613E+01	0.385E+00	INTAKE VS. DISCHARGE	0.853E+00	0.385E+00
12/13/77	0700	I5	0	0.673E+01	0.179E+00			
12/13/77	0710	D1	0	0.655E+01	0.193E+00	INTAKE VS. DISCHARGE	0.458E+00	0.521E+00

TABLE 45. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
03/07/77	2053	I5	0	0.521E-01	0.248E-01	INTAKE VS. DISCHARGE	0.306E+01	0.118E+00
03/07/77	2102	D1	0	0.706E-02	0.706E-02			
03/07/77	2053	I5	36	0.400E-06	0.245E-06	INTAKE V. DISCHARGE	0.400E+00	0.548E+00
03/07/77	2102	D1	36	0.200E-06	0.200E-06			
03/08/77	0536	I5	0	0.140E-01	0.141E-01			
03/08/77	0544	D1	0	0.218E-01	0.939E-02	INTAKE VS. DISCHARGE	0.229E+00	0.647E+00
03/08/77	1248	I5	0	0.400E-06	0.245E-06			
03/08/77	1255	D1	0	0.500E-06	0.289E-06	INTAKE VS. DISCHARGE	0.707E-01	0.787E+00
04/11/77	2105	I5	0	0.162E-01	0.162E-01			
04/11/77	2115	D1	0	0.940E-01	0.466E-01	INTAKE VS. DISCHARGE	0.249E+01	0.153E+00
04/11/77	2105	I5	39	0.250E-06	0.250E-06			
04/11/77	2115	D1	39	0.353E-01	0.217E-01	INTAKE VS. DISCHARGE	0.205E+01	0.195E+00
04/12/77	0434	I5	0	0.202E-01	0.202E-01			
04/12/77	0443	D1	0	0.422E-01	0.422E-01	INTAKE VS. DISCHARGE	0.221E+00	0.650E+00
04/12/77	1220	I5	0	0.154E+00	0.892E-01			
04/12/77	1235	D1	0	0.200E-06	0.200E-06	INTAKE VS. DISCHARGE	0.388E+01	0.898E-01
05/16/77	2245	I5	0	0.310E-01	0.281E-01			
05/16/77	2245	D1	0	0.400E-06	0.245E-06	INTAKE VS. DISCHARGE	0.122E+01	0.303E+00
05/16/77	2245	I5	36	0.782E-02	0.782E-02			
05/16/77	2245	D1	36	0.337E-01	0.221E-01	INTAKE VS. DISCHARGE	0.148E+01	0.264E+00
05/17/77	0434	I5	0	0.129E-01	0.129E-01			
05/17/77	0443	D1	0	0.600E-06	0.245E-06	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
05/17/77	1220	I5	0	0.200E-06	0.200E-06			
05/17/77	1235	D1	0	0.163E-01	0.150E-01	INTAKE VS. DISCHARGE	0.119E+01	0.309E+00
06/13/77	0045	I5	0	0.200E-06	0.200E-06			
06/13/77	0027	D1	0	0.806E-01	0.613E-01	INTAKE VS. DISCHARGE	0.224E+01	0.178E+00
06/13/77	0045	I5	35	0.400E-06	0.245E-06			
06/13/77	0027	D1	35	0.214E-01	0.164E-01	INTAKE VS. DISCHARGE	0.171E+01	0.228E+00
06/14/77	0325	I5	0	0.699E-02	0.558E-02			
06/14/77	0315	D1	0	0.102E+00	0.516E-01	INTAKE VS. DISCHARGE	0.334E+01	0.105E+00
06/14/77	1250	I5	0	0.200E+00	0.200E+00			
06/14/77	1235	D1	0	0.276E+00	0.206E+00	INTAKE VS. DISCHARGE	0.705E-01	0.786E+00



TABLE 45. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
07/11/77	2335	I5	0	0.983E-01	0.695E-01			
07/11/77	2346	D1	0	0.531E-01	0.233E-01	INTAKE VS. DISCHARGE	0.380E+00	0.558E+00
07/11/77	2335	I5	33	0.492E-01	0.304E-01			
07/11/77	2346	D1	33	0.123E+00	0.105E+00	INTAKE VS. DISCHARGE	0.452E+00	0.524E+00
07/12/77	0423	I5	0	0.191E-01	0.191E-01			
07/12/77	0433	D1	0	0.500E-06	0.289E-06	INTAKE VS. DISCHARGE	0.778E+00	0.410E+00
07/12/77	1428	I5	0	0.400E-06	0.245E-06			
07/12/77	1440	D1	0	0.104E-01	0.104E-01	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
08/08/77	2210	I5	0	0.412E-02	0.412E-02			
08/08/77	2200	D1	0	0.840E-02	0.840E-02	INTAKE VS. DISCHARGE	0.209E+00	0.659E+00
08/08/77	2210	I5	37	0.577E-02	0.331E-02			
08/08/77	2200	D1	37	0.142E-01	0.142E-01	INTAKE VS. DISCHARGE	0.562E+00	0.486E+00
08/09/77	0415	I5	0	0.200E-06	0.200E-06			
08/09/77	0423	D1	0	0.330E-01	0.330E-01	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
08/09/77	1250	I5	0	0.244E-01	0.244E-01			
08/09/77	1305	D1	0	0.946E-02	0.946E-02	INTAKE VS. DISCHARGE	0.389E+00	0.555E+00
09/12/77	2036	I5	0	0.392E-02	0.392E-02			
09/12/77	2055	D1	0	0.153E-01	0.926E-02	INTAKE VS. DISCHARGE	0.128E+01	0.292E+00
09/12/77	2036	I5	35	0.600E-06	0.245E-06			
09/12/77	2055	D1	35	0.900E-02	0.900E-02	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
09/13/77	0539	I5	0	0.318E-01	0.318E-01			
09/13/77	0525	D1	0	0.149E+00	0.149E+00	INTAKE VS. DISCHARGE	0.591E+00	0.468E+00
09/13/77	1200	I5	0	0.600E-06	0.245E-06			
09/13/77	1220	D1	0	0.194E+00	0.165E+00	INTAKE VS. DISCHARGE	0.139E+01	0.273E+00
10/10/77	2117	I5	0	0.0	0.0			
10/10/77	2104	D1	0	0.375E-01	0.274E-01	INTAKE VS. DISCHARGE	0.187E+01	0.208E+00
10/10/77	2117	I5	38	0.504E-02	0.504E-02			
10/10/77	2104	D1	38	0.437E-01	0.416E-01	INTAKE VS. DISCHARGE	0.851E+00	0.386E+00
10/11/77	0658	I5	0	0.0	0.0			
10/11/77	0651	D1	0	0.388E-02	0.388E-02	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
10/11/77	1408	I5	0	0.167E-01	0.112E-01			
10/11/77	1321	D1	0	0.122E-02	0.122E-02	INTAKE VS. DISCHARGE	0.189E+01	0.206E+00

TABLE 45. MEAN CHLOROPHYLL B CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
11/07/77	1927	I5	0	0.0	0.0	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
11/07/77	1910	D1	0	0.200E-06	0.200E-06	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
11/07/77	1927	I5	37	0.0	0.0	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
11/07/77	1910	D1	37	0.696E-01	0.696E-01	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
11/08/77	0659	I5	0	0.0	0.0	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
11/08/77	0650	D1	0	0.200E-06	0.200E-06	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
11/08/77	1211	I5	0	0.0	0.0	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
11/08/77	1148	D1	0	0.200E-06	0.200E-06	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
12/12/77	1355	I5	0	0.444E-04	0.444E-04	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
12/12/77	1355	D1	0	0.0	0.0	INTAKE VS. DISCHARGE	0.100E+01	0.348E+00
12/12/77	1840	I5	02	0.566E-02	0.566E-02	INTAKE VS. DISCHARGE	0.331E+00	0.583E+00
12/12/77	1840	D1	02	0.148E-01	0.148E-01	INTAKE VS. DISCHARGE	0.331E+00	0.583E+00
12/12/77	1840	I5	22	0.0	0.0	INTAKE VS. DISCHARGE	0.261E+01	0.145E+00
12/12/77	1840	D1	22	0.198E-01	0.123E-01	INTAKE VS. DISCHARGE	0.261E+01	0.145E+00
12/12/77	1928	I5	0	0.544E-01	0.544E-01	INTAKE VS. DISCHARGE	0.133E+01	0.284E+00
12/12/77	1940	D1	0	0.243E+00	0.155E+00	INTAKE VS. DISCHARGE	0.133E+01	0.284E+00
12/13/77	0700	I5	0	0.0	0.0	INTAKE VS. DISCHARGE	0.637E+01	0.360E-01
12/13/77	0710	D1	0	0.198E+00	0.786E-01	INTAKE VS. DISCHARGE	0.637E+01	0.360E-01

TABLE 46. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
07/11/77	2335	I5 0	5	0.709E+00	0.116E+00			
07/11/77	2346	D1 0	5	0.610E+00	0.661E-01	INTAKE VS. DISCHARGE	0.549E+00	0.484E+00
07/11/77	2335	I5 33	5	0.550E+00	0.935E-01			
07/11/77	2346	D1 33	5	0.344E+00	0.109E+00	INTAKE VS. DISCHARGE	0.227E+01	0.170E+00
07/12/77	0423	I5 0	5	0.572E+00	0.942E-01			
07/12/77	0433	D1 0	4	0.283E+00	0.288E-01	INTAKE VS. DISCHARGE	0.692E+01	0.345E-01
07/12/77	1428	I5 0	5	0.427E+00	0.874E-01			
07/12/77	1440	D1 0	5	0.291E+00	0.972E-01	INTAKE VS. DISCHARGE	0.107E+01	0.333E+00
08/08/77	2210	I5 0	5	0.233E+00	0.130E+00			
08/08/77	2200	D1 0	5	0.186E+00	0.136E+00	INTAKE VS. DISCHARGE	0.621E-01	0.798E+00
08/08/77	2210	I5 37	5	0.200E+00	0.800E-01			
08/08/77	2200	D1 37	3	0.218E+00	0.156E+00	INTAKE VS. DISCHARGE	0.122E-01	0.903E+00
08/09/77	0415	I5 0	5	0.221E+00	0.530E-01			
08/09/77	0423	D1 0	5	0.102E+00	0.679E-01	INTAKE VS. DISCHARGE	0.190E+01	0.205E+00
08/09/77	1250	I5 0	4	0.285E+00	0.107E+00			
08/09/77	1305	D1 0	5	0.158E+00	0.894E-01	INTAKE VS. DISCHARGE	0.851E+00	0.390E+00
09/12/77	2036	I5 0	5	0.471E+00	0.958E-01			
09/12/77	2055	D1 0	5	0.555E+00	0.103E+00	INTAKE VS. DISCHARGE	0.356E+00	0.570E+00
09/12/77	2036	I5 35	5	0.315E+00	0.873E-01			
09/12/77	2055	D1 35	5	0.323E+00	0.966E-01	INTAKE VS. DISCHARGE	0.420E-02	0.939E+00
09/13/77	0539	I5 0	5	0.449E+00	0.587E-01			
09/13/77	0525	D1 0	5	0.485E+00	0.127E+00	INTAKE VS. DISCHARGE	0.652E-01	0.793E+00
09/13/77	1200	I5 0	5	0.562E+00	0.470E-01			
09/13/77	1220	D1 0	5	0.125E+01	0.669E+00	INTAKE VS. DISCHARGE	0.105E+01	0.338E+00
10/10/77	2117	I5 0	5	0.128E+01	0.513E-01			
10/10/77	2104	D1 0	5	0.135E+01	0.113E+00	INTAKE VS. DISCHARGE	0.270E+00	0.618E+00
10/10/77	2117	I5 38	5	0.151E+01	0.782E-01			
10/10/77	2104	D1 38	5	0.124E+01	0.561E-01	INTAKE VS. DISCHARGE	0.799E+01	0.229E-01
10/11/77	0658	I5 0	5	0.151E+01	0.113E+00			
10/11/77	0651	D1 0	5	0.151E+01	0.735E-01	INTAKE VS. DISCHARGE	0.884E-03	0.966E+00
10/11/77	1408	I5 0	5	0.167E+01	0.116E+00			
10/11/77	1321	D1 0	5	0.152E+01	0.710E-01	INTAKE VS. DISCHARGE	0.132E+01	0.284E+00

TABLE 46. MEAN CHLOROPHYLL C CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
03/07/77	2053	I5	0	0.170E+01	0.119E+00	INTAKE VS. DISCHARGE	0.825E+00	0.393E+00
03/07/77	2102	D1	0	0.154E+01	0.133E+00			
03/07/77	2053	I5	36	0.129E+01	0.882E-01	INTAKE V. DISCHARGE	0.289E+01	0.127E+00
03/07/77	2102	D1	36	0.851E+00	0.245E+00			
03/08/77	0536	I5	0	0.125E+01	0.193E+00	INTAKE VS. DISCHARGE	0.802E-01	0.775E+00
03/08/77	0544	D1	0	0.119E+01	0.117E+00			
03/08/77	1248	I5	0	0.999E+00	0.202E+00	INTAKE VS. DISCHARGE	0.141E+01	0.275E+00
03/08/77	1255	D1	0	0.129E+01	0.113E+00			
04/11/77	2105	I5	0	0.209E+01	0.113E+00	INTAKE VS. DISCHARGE	0.127E+01	0.293E+00
04/11/77	2115	D1	0	0.230E+01	0.150E+00			
04/11/77	2105	I5	39	0.189E+01	0.369E+00	INTAKE VS. DISCHARGE	0.257E+00	0.628E+00
04/11/77	2115	D1	39	0.206E+01	0.115E+00			
04/12/77	0434	I5	0	0.218E+01	0.225E+00	INTAKE VS. DISCHARGE	0.191E+01	0.204E+00
04/12/77	0443	D1	0	0.178E+01	0.180E+00			
04/12/77	1220	I5	0	0.206E+01	0.233E+00	INTAKE VS. DISCHARGE	0.710E+00	0.431E+00
04/12/77	1235	D1	0	0.186E+01	0.105E+00			
05/16/77	2245	I5	0	0.670E+00	0.789E-01	INTAKE VS. DISCHARGE	0.375E+00	0.560E+00
05/16/77	2245	D1	0	0.599E+00	0.850E-01			
05/16/77	2245	I5	36	0.429E+00	0.891E-01	INTAKE VS. DISCHARGE	0.851E-01	0.769E+00
05/16/77	2245	D1	36	0.470E+00	0.112E+00			
05/17/77	0434	I5	0	0.748E+00	0.657E-01	INTAKE VS. DISCHARGE	0.169E+00	0.689E+00
05/17/77	0443	D1	0	0.786E+00	0.654E-01			
05/17/77	1220	I5	0	0.777E+00	0.256E+00	INTAKE VS. DISCHARGE	0.715E+00	0.426E+00
05/17/77	1235	D1	0	0.102E+01	0.125E+00			
06/13/77	0045	I5	0	0.170E+01	0.642E-01	INTAKE VS. DISCHARGE	0.398E+01	0.864E-01
06/13/77	0027	D1	0	0.133E+01	0.198E+00			
06/13/77	0045	I5	35	0.989E+00	0.919E-01	INTAKE VS. DISCHARGE	0.325E+01	0.109E+00
06/13/77	0027	D1	35	0.813E+00	0.339E-01			
06/14/77	0325	I5	0	0.155E+01	0.202E+00	INTAKE VS. DISCHARGE	0.458E+00	0.521E+00
06/14/77	0315	D1	0	0.138E+01	0.129E+00			
06/14/77	1250	I5	0	0.152E+01	0.644E+00	INTAKE VS. DISCHARGE	0.471E-01	0.821E+00
06/14/77	1235	D1	0	0.173E+01	0.739E+00			

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DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
11/07/77	1927	I5	0	0.253E+01	0.218E+00			
11/07/77	1910	D1	0	0.192E+01	0.502E-01	INTAKE VS. DISCHARGE	0.737E+01	0.270E-01
11/07/77	1927	I5	37	0.299E+01	0.193E-01			
11/07/77	1910	D1	37	0.213E+01	0.250E+00	INTAKE VS. DISCHARGE	0.119E+02	0.976E-02
11/08/77	0659	I5	0	0.217E+01	0.163E+00			
11/08/77	0650	D1	0	0.174E+01	0.180E+00	INTAKE VS. DISCHARGE	0.308E+01	0.117E+00
11/08/77	1211	I5	0	0.196E+01	0.549E-01			
11/08/77	1148	D1	0	0.144E+01	0.133E+00	INTAKE VS. DISCHARGE	0.129E+02	0.792E-02
12/12/77	1355	I5	0	0.183E+01	0.937E-01			
12/12/77	1355	D1	0	0.144E+01	0.849E-01	INTAKE VS. DISCHARGE	0.942E+01	0.161E-01
12/12/77	1840	I5	02	0.148E+01	0.748E-01			
12/12/77	1840	D1	02	0.146E+01	0.939E-01	INTAKE VS. DISCHARGE	0.400E-01	0.833E+00
12/12/77	1840	I5	22	0.156E+01	0.112E+00			
12/12/77	1840	D1	22	0.156E+01	0.104E+00	INTAKE VS. DISCHARGE	0.0	0.100E+01
12/12/77	1928	I5	0	0.161E+01	0.759E-01			
12/12/77	1940	D1	0	0.151E+01	0.149E+00	INTAKE VS. DISCHARGE	0.313E+00	0.593E+00
12/13/77	0700	I5	0	0.165E+01	0.751E-01			
12/13/77	0710	D1	0	0.156E+01	0.676E-01	INTAKE VS. DISCHARGE	0.658E+00	0.445E+00

TABLE 47. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD		COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
					ERROR				
03/07/77	2053	I5	0	0.673E+00	0.225E+00		INTAKE VS. DISCHARGE	0.310E+00	0.595E+00
03/07/77	2102	D1	0	0.832E+00	0.175E+00				
03/07/77	2053	I5	36	0.813E+00	0.868E-01		INTAKE V. DISCHARGE	0.105E+01	0.338E+00
03/07/77	2102	D1	36	0.515E+00	0.278E+00				
03/08/77	0536	I5	0	0.978E+00	0.795E-01		INTAKE VS. DISCHARGE	0.546E-01	0.809E+00
03/08/77	0544	D1	0	0.948E+00	0.930E-01				
03/08/77	1248	I5	0	0.0	0.0		INTAKE VS. DISCHARGE	0.383E+01	0.915E-01
03/08/77	1255	D1	0	0.743E+00	0.432E+00				
04/11/77	2105	I5	0	0.538E+00	0.489E+00		INTAKE VS. DISCHARGE	0.395E+01	0.820E-01
04/11/77	2115	D1	0	0.222E+01	0.688E+00				
04/11/77	2105	I5	39	0.0	0.0		INTAKE VS. DISCHARGE	0.955E+01	0.184E-01
04/11/77	2115	D1	39	0.132E+01	0.375E+00				
04/12/77	0434	I5	0	0.0	0.0		INTAKE VS. DISCHARGE	0.247E+01	0.154E+00
04/12/77	1220	I5	0	0.277E+00	0.176E+00				
04/12/77	1235	D1	0	0.581E+00	0.202E+00		INTAKE VS. DISCHARGE	0.165E+01	0.240E+00
05/16/77	2245	I5	0	0.297E+00	0.116E+00				
05/16/77	2245	D1	0	0.308E+00	0.125E+00		INTAKE VS. DISCHARGE	0.158E+01	0.245E+00
05/16/77	2245	D1	0	0.472E+00	0.376E-01				
05/16/77	2245	I5	36	0.478E+00	0.169E+00		INTAKE VS. DISCHARGE	0.313E+00	0.595E+00
05/16/77	2245	D1	36	0.342E+00	0.171E+00				
05/17/77	0434	I5	0	0.575E+00	0.129E+00		INTAKE VS. DISCHARGE	0.421E+00	0.538E+00
05/17/77	0443	D1	0	0.453E+00	0.136E+00				
05/17/77	1220	I5	0	0.341E+00	0.105E+00		INTAKE VS. DISCHARGE	0.793E-02	0.919E+00
05/17/77	1235	D1	0	0.328E+00	0.962E-01				
06/13/77	0045	I5	0	0.146E+01	0.228E+00		INTAKE VS. DISCHARGE	0.484E+00	0.512E+00
06/13/77	0027	D1	0	0.171E+01	0.283E+00				
06/13/77	0045	I5	35	0.756E+00	0.771E-01		INTAKE VS. DISCHARGE	0.233E+02	0.196E-02
06/13/77	0027	D1	35	0.147E+01	0.127E+00				
06/14/77	0325	I5	0	0.689E+00	0.126E+00		INTAKE VS. DISCHARGE	0.179E+02	0.362E-02
06/14/77	0315	D1	0	0.160E+01	0.174E+00				
06/14/77	1250	I5	0	0.103E+01	0.421E+00		INTAKE VS. DISCHARGE	0.481E+00	0.511E+00
06/14/77	1235	D1	0	0.146E+01	0.459E+00				

TABLE 47. MEAN PHAEOPHYTIN A CONCENTRATIONS (MILLIGRAMS PER CUBIC METER) WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE	
07/11/77	2335	I5	0	5	0.125E+00	0.673E-01			
07/11/77	2346	D1	0	5	0.826E+00	0.618E-01	INTAKE VS. DISCHARGE	0.589E+02	0.231E-03
07/11/77	2335	I5	33	5	0.135E+00	0.135E+00			
07/11/77	2346	D1	33	5	0.691E+00	0.122E+00	INTAKE VS. DISCHARGE	0.938E+01	0.162E-01
07/12/77	0423	I5	0	5	0.707E+00	0.119E+00			
07/12/77	0433	D1	0	4	0.321E+00	0.197E+00	INTAKE VS. DISCHARGE	0.310E+01	0.122E+00
07/12/77	1428	I5	0	5	0.136E+00	0.851E-01			
07/12/77	1440	D1	0	5	0.207E+00	0.571E-01	INTAKE VS. DISCHARGE	0.480E+00	0.512E+00
08/08/77	2210	I5	0	5	0.118E+00	0.118E+00			
08/08/77	2200	D1	0	5	0.690E-01	0.690E-01	INTAKE VS. DISCHARGE	0.128E+00	0.724E+00
08/08/77	2210	I5	37	5	0.119E+00	0.564E-01			
08/08/77	2200	D1	37	3	0.103E+00	0.411E-01	INTAKE VS. DISCHARGE	0.415E-01	0.832E+00
08/09/77	0415	I5	0	5	0.811E-01	0.778E-01			
08/09/77	0423	D1	0	5	0.118E-01	0.118E-01	INTAKE VS. DISCHARGE	0.778E+00	0.407E+00
08/09/77	1250	I5	0	4	0.167E+00	0.631E-01			
08/09/77	1305	D1	0	5	0.161E+00	0.849E-01	INTAKE VS. DISCHARGE	0.308E-02	0.946E+00
09/12/77	2036	I5	0	5	0.994E-01	0.649E-01			
09/12/77	2055	D1	0	5	0.884E-01	0.397E-01	INTAKE VS. DISCHARGE	0.213E-01	0.874E+00
09/12/77	2036	I5	35	5	0.199E+00	0.115E+00			
09/12/77	2055	D1	35	5	0.422E+00	0.170E+00	INTAKE VS. DISCHARGE	0.119E+01	0.308E+00
09/13/77	0539	I5	0	5	0.192E+00	0.119E+00			
09/13/77	0525	D1	0	5	0.111E+00	0.536E-01	INTAKE VS. DISCHARGE	0.377E+00	0.559E+00
09/13/77	1200	I5	0	5	0.109E+00	0.602E-01			
09/13/77	1220	D1	0	5	0.293E+00	0.184E+00	INTAKE VS. DISCHARGE	0.905E+00	0.372E+00
10/10/77	2117	I5	0	5	0.221E+00	0.149E+00			
10/10/77	2104	D1	0	5	0.866E+00	0.139E+00	INTAKE VS. DISCHARGE	0.100E+02	0.141E-01
10/10/77	2117	I5	38	5	0.405E+00	0.189E+00			
10/10/77	2104	D1	38	5	0.629E+00	0.209E+00	INTAKE VS. DISCHARGE	0.632E+00	0.454E+00
10/11/77	0658	I5	0	5	0.765E+00	0.253E+00			
10/11/77	0651	D1	0	5	0.104E+01	0.198E+00	INTAKE VS. DISCHARGE	0.749E+00	0.415E+00
10/11/77	1408	I5	0	5	0.498E+00	0.210E+00			
10/11/77	1321	D1	0	5	0.784E+00	0.178E+00	INTAKE VS. DISCHARGE	0.108E+01	0.331E+00

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DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
11/07/77	1927	I5 0	5	0.500E+00	0.107E+00	INTAKE VS. DISCHARGE	0.771E+00	0.409E+00
11/07/77	1910	D1 0	5	0.306E+00	0.194E+00			
11/07/77	1927	I5 37	5	0.319E+00	0.150E+00			
11/07/77	1910	D1 37	5	0.899E+00	0.680E+00	INTAKE VS. DISCHARGE	0.694E+00	0.433E+00
11/08/77	0659	I5 0	5	0.360E+00	0.184E+00			
11/08/77	0650	D1 0	5	0.178E+00	0.546E-01	INTAKE VS. DISCHARGE	0.899E+00	0.373E+00
11/08/77	1211	I5 0	5	0.269E+00	0.154E+00			
11/08/77	1148	D1 0	5	0.189E+00	0.939E-01	INTAKE VS. DISCHARGE	0.194E+00	0.669E+00
12/12/77	1355	I5 0	5	0.665E+00	0.241E+00			
12/12/77	1355	D1 0	5	0.701E+00	0.132E+00	INTAKE VS. DISCHARGE	0.172E-01	0.885E+00
12/12/77	1840	I5 02	5	0.988E+00	0.909E-01			
12/12/77	1840	D1 02	5	0.852E+00	0.129E+00	INTAKE VS. DISCHARGE	0.748E+00	0.416E+00
12/12/77	1840	I5 22	5	0.631E+00	0.227E+00			
12/12/77	1840	D1 22	5	0.860E+00	0.868E-01	INTAKE VS. DISCHARGE	0.889E+00	0.376E+00
12/12/77	1928	I5 0	5	0.879E+00	0.209E+00			
12/12/77	1940	D1 0	5	0.116E+01	0.239E+00	INTAKE VS. DISCHARGE	0.804E+00	0.399E+00
12/13/77	0700	I5 0	5	0.103E+01	0.233E+00			
12/13/77	0710	D1 0	5	0.112E+01	0.262E+00	INTAKE VS. DISCHARGE	0.683E-01	0.789E+00



TABLE 48. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
03/07/77	2053	I5 0	5	0.145E+00	0.496E-01			
03/07/77	2102	D1 0	5	0.186E+00	0.375E-01	INTAKE VS. DISCHARGE	0.441E+00	0.529E+00
03/07/77	2053	I5 36	5	0.151E+00	0.161E-01			
03/07/77	2102	D1 36	5	0.909E-01	0.511E-01	INTAKE V. DISCHARGE	0.124E+01	0.299E+00
03/08/77	0536	I5 0	4	0.206E+00	0.162E-01			
03/08/77	0544	D1 0	5	0.219E+00	0.241E-01	INTAKE VS. DISCHARGE	0.170E+00	0.689E+00
03/08/77	1248	I5 0	5	0.0	0.0			
03/08/77	1255	D1 0	4	0.140E+00	0.810E-01	INTAKE VS. DISCHARGE	0.386E+01	0.904E-01
04/11/77	2105	I5 0	5	0.688E-01	0.639E-01			
04/11/77	2115	D1 0	5	0.298E+00	0.975E-01	INTAKE VS. DISCHARGE	0.385E+01	0.852E-01
04/11/77	2105	I5 39	4	0.0	0.0			
04/11/77	2115	D1 39	5	0.116E+00	0.483E-01	INTAKE VS. DISCHARGE	0.448E+01	0.724E-01
04/12/77	0434	I5 0	5	0.0	0.0			
04/12/77	0443	D1 0	5	0.339E-01	0.216E-01	INTAKE VS. DISCHARGE	0.246E+01	0.155E+00
04/12/77	1220	I5 0	4	0.895E-01	0.327E-01			
04/12/77	1235	D1 0	5	0.458E-01	0.180E-01	INTAKE VS. DISCHARGE	0.153E+01	0.256E+00
05/16/77	2245	I5 0	5	0.167E+00	0.703E-01			
05/16/77	2245	D1 0	5	0.294E+00	0.385E-01	INTAKE VS. DISCHARGE	0.251E+01	0.152E+00
05/16/77	2245	I5 36	5	0.320E+00	0.129E+00			
05/16/77	2245	D1 36	4	0.238E+00	0.123E+00	INTAKE VS. DISCHARGE	0.208E+00	0.661E+00
05/17/77	0434	I5 0	5	0.262E+00	0.604E-01			
05/17/77	0443	D1 0	5	0.229E+00	0.738E-01	INTAKE VS. DISCHARGE	0.116E+00	0.735E+00
05/17/77	1220	I5 0	5	0.948E-01	0.303E-01			
05/17/77	1235	D1 0	5	0.115E+00	0.343E-01	INTAKE VS. DISCHARGE	0.201E+00	0.664E+00
06/13/77	0045	I5 0	5	0.275E+00	0.503E-01			
06/13/77	0027	D1 0	4	0.418E+00	0.434E-01	INTAKE VS. DISCHARGE	0.435E+01	0.756E-01
06/13/77	0045	I5 35	5	0.152E+00	0.150E-01			
06/13/77	0027	D1 35	5	0.345E+00	0.357E-01	INTAKE VS. DISCHARGE	0.249E+02	0.164E-02
06/14/77	0325	I5 0	5	0.148E+00	0.341E-01			
06/14/77	0315	D1 0	5	0.419E+00	0.107E+00	INTAKE VS. DISCHARGE	0.584E+01	0.424E-01
06/14/77	1250	I5 0	5	0.295E+00	0.140E+00			
06/14/77	1215	D1 0	5	0.451E+00	0.156E+00	INTAKE VS. DISCHARGE	0.560E+00	0.480E+00

TABLE 48. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
07/11/77	2335 I5	0	0.421E-01	0.242E-01	INTAKE VS. DISCHARGE	0.576E+02	0.242E-03
07/11/77	2346 D1	0	0.352E+00	0.329E-01	INTAKE VS. DISCHARGE	0.563E+01	0.453E-01
07/11/77	2335 I5	33	0.504E-01	0.504E-01	INTAKE VS. DISCHARGE	0.111E+01	0.328E+00
07/11/77	2346 D1	33	0.266E+00	0.758E-01	INTAKE VS. DISCHARGE	0.736E+00	0.419E+00
07/12/77	0423 I5	0	0.268E+00	0.489E-01	INTAKE VS. DISCHARGE	0.540E-02	0.932E+00
07/12/77	0433 D1	0	0.155E+00	0.104E+00	INTAKE VS. DISCHARGE	0.782E-01	0.778E+00
07/12/77	1428 I5	0	0.700E-01	0.439E-01	INTAKE VS. DISCHARGE	0.787E+00	0.404E+00
07/12/77	1440 D1	0	0.117E+00	0.331E-01	INTAKE VS. DISCHARGE	0.248E+00	0.634E+00
08/08/77	2210 I5	0	0.768E-01	0.768E-01	INTAKE VS. DISCHARGE	0.254E-01	0.864E+00
08/08/77	2200 D1	0	0.692E-01	0.692E-01	INTAKE VS. DISCHARGE	0.224E+01	0.173E+00
08/08/77	2210 I5	37	0.811E-01	0.383E-01	INTAKE VS. DISCHARGE	0.350E+00	0.573E+00
08/08/77	2200 D1	37	0.658E-01	0.261E-01	INTAKE VS. DISCHARGE	0.117E+01	0.313E+00
08/09/77	0415 I5	0	0.599E-01	0.580E-01	INTAKE VS. DISCHARGE	0.936E+01	0.163E-01
08/09/77	0423 D1	0	0.790E-02	0.790E-02	INTAKE VS. DISCHARGE	0.992E+00	0.350E+00
08/09/77	1250 I5	0	0.958E-01	0.351E-01	INTAKE VS. DISCHARGE	0.885E+00	0.377E+00
08/09/77	1305 D1	0	0.148E+00	0.883E-01	INTAKE VS. DISCHARGE	0.115E+01	0.316E+00
09/12/77	2036 I5	0	0.470E-01	0.308E-01	INTAKE VS. DISCHARGE		
09/12/77	2055 D1	0	0.413E-01	0.184E-01	INTAKE VS. DISCHARGE		
09/12/77	2036 I5	35	0.121E+00	0.733E-01	INTAKE VS. DISCHARGE		
09/12/77	2055 D1	35	0.411E+00	0.179E+00	INTAKE VS. DISCHARGE		
09/13/77	0539 I5	0	0.779E-01	0.491E-01	INTAKE VS. DISCHARGE		
09/13/77	0525 D1	0	0.460E-01	0.224E-01	INTAKE VS. DISCHARGE		
09/13/77	1200 I5	0	0.441E-01	0.257E-01	INTAKE VS. DISCHARGE		
09/13/77	1220 D1	0	0.143E+00	0.883E-01	INTAKE VS. DISCHARGE		
10/10/77	2117 I5	0	0.460E-01	0.323E-01	INTAKE VS. DISCHARGE		
10/10/77	2104 D1	0	0.191E+00	0.347E-01	INTAKE VS. DISCHARGE		
10/10/77	2117 I5	38	0.755E-01	0.355E-01	INTAKE VS. DISCHARGE		
10/10/77	2104 D1	38	0.136E+00	0.494E-01	INTAKE VS. DISCHARGE		
10/11/77	0658 I5	0	0.144E+00	0.493E-01	INTAKE VS. DISCHARGE		
10/11/77	0651 D1	0	0.208E+00	0.467E-01	INTAKE VS. DISCHARGE		
10/11/77	1408 I5	0	0.868E-01	0.401E-01	INTAKE VS. DISCHARGE		
10/11/77	1321 D1	0	0.143E+00	0.334E-01	INTAKE VS. DISCHARGE		

TABLE 48. MEAN PHAEOPHYTIN A TO CHLOROPHYLL A RATIO WITH STANDARD ERRORS AND COMPARISON OF MEANS USING ONE-WAY ANALYSIS OF VARIANCE. THE INC. COLUMN IS SAMPLE TYPE (I1=MTR1-1, I3=MTR1-3, I5=MTR1-5, I6=MTR1-6, D=DISCHARGE) AND NUMBER OF HOURS AFTER COLLECTION IT WAS INCUBATED.

DATE	TIME	INC.	SAMPLES	MEAN	STANDARD ERROR	COMPARISON BETWEEN	P-STATISTIC	SIGNIFICANCE
11/07/77	1927	I5	0	0.654E-01	0.121E-01			
11/07/77	1910	D1	0	0.529E-01	0.338E-01	INTAKE VS. DISCHARGE	0.121E+00	0.731E+00
11/07/77	1927	I5	37	0.386E-01	0.183E-01			
11/07/77	1910	D1	37	0.252E+00	0.215E+00	INTAKE VS. DISCHARGE	0.985E+00	0.352E+00
11/08/77	0659	I5	0	0.637E-01	0.373E-01			
11/08/77	0650	D1	0	0.344E-01	0.122E-01	INTAKE VS. DISCHARGE	0.557E+00	0.481E+00
11/08/77	1211	I5	0	0.453E-01	0.267E-01			
11/08/77	1148	D1	0	0.364E-01	0.177E-01	INTAKE VS. DISCHARGE	0.776E-01	0.777E+00
12/12/77	1355	I5	0	0.978E-01	0.377E-01			
12/12/77	1355	D1	0	0.106E+00	0.200E-01	INTAKE VS. DISCHARGE	0.339E-01	0.845E+00
12/12/77	1840	I5	02	0.167E+00	0.197E-01			
12/12/77	1840	D1	02	0.139E+00	0.197E-01	INTAKE VS. DISCHARGE	0.101E+01	0.346E+00
12/12/77	1840	I5	22	0.889E-01	0.329E-01			
12/12/77	1840	D1	22	0.126E+00	0.146E-01	INTAKE VS. DISCHARGE	0.104E+01	0.340E+00
12/12/77	1928	I5	0	0.134E+00	0.323E-01			
12/12/77	1940	D1	0	0.200E+00	0.508E-01	INTAKE VS. DISCHARGE	0.120E+01	0.307E+00
12/13/77	0700	I5	0	0.157E+00	0.402E-01			
12/13/77	0710	D1	0	0.177E+00	0.479E-01	INTAKE VS. DISCHARGE	0.104E+00	0.747E+00

exact cause of the greater plant impact during 1977 is unknown at this time. However, the increase in the number of times in which changes in phytoplankton viability were detected is in part due to methodology changes which allowed statistically significant smaller changes to be detected during 1977.

Table 49 summarizes results in those instances where decreased phytoplankton viability was indicated following plant passage. The sole instance of increased viability was an increase in chlorophyll b on 12/13/77 at 0700 hours. Since our sampling time on September 12 coincided with chlorination, the decrease in viability evident for the incubated sample collected at 2036 and 2055 EST is most likely a result of chlorination.

#### Monthly Variation of the Chlorophylls and Phaeophytin a

Figures 73 through 77 illustrate the variation of chlorophyll a, chlorophyll b, chlorophyll c, phaeophytin a, and the phaeophytin a/chlorophyll a ratio during 1977 at the intake forebay of the Donald C. Cook Nuclear Plant. Chlorophylls a and c were relatively high during March, April, June, October, November, and December. Chlorophyll b was high during March and August. Phaeophytin a exhibited peaks in its concentration during March, June, and October. The phaeophytin a/chlorophyll a ratio was highest in June and ranged between 0.05 and 0.22 during the other months. It was generally lower than those of 1975 and 1976. (Rossmann et al. 1977, Rossmann et al. 1979).

TABLE 49. Summary of instances of decreased viability between intake and discharge.

Date	Time	Incubation	Decrease in Chlorophyll			Increase in Phaeophytin <u>a</u>	Increase in Ratio
			<u>a</u>	<u>b</u>	<u>c</u>		
03/08/77	Dawn	No	X				
03/08/77	Noon	No	X				
04/11/77	Dusk	Yes	X			X	
04/12/77	Dawn	No	X				
05/16/77	Dusk	No	X				
05/17/77	Noon	No	X				
06/13/77	Dusk	No	X				
06/13/77	Dusk	Yes	X			X	X
06/14/77	Dawn	No				X	X
07/11/77	Dusk	No	X			X	X
07/11/77	Dusk	Yes	X			X	X
07/12/77	Noon	No	X				
07/12/77	Dawn	No		X			
09/12/77	Dusk	Yes	X				
10/10/77	Dusk	Yes	X				
10/10/77	Dusk	No					X
11/07/77	Dusk	Yes	X	X			
11/07/77	Dusk	No		X			
11/08/77	Noon	No	X	X			
12/12/77	Noon	No		X			
12/13/77	Dawn	No					

# CHLOROPHYLL A

MEANS AND STANDARD ERRORS

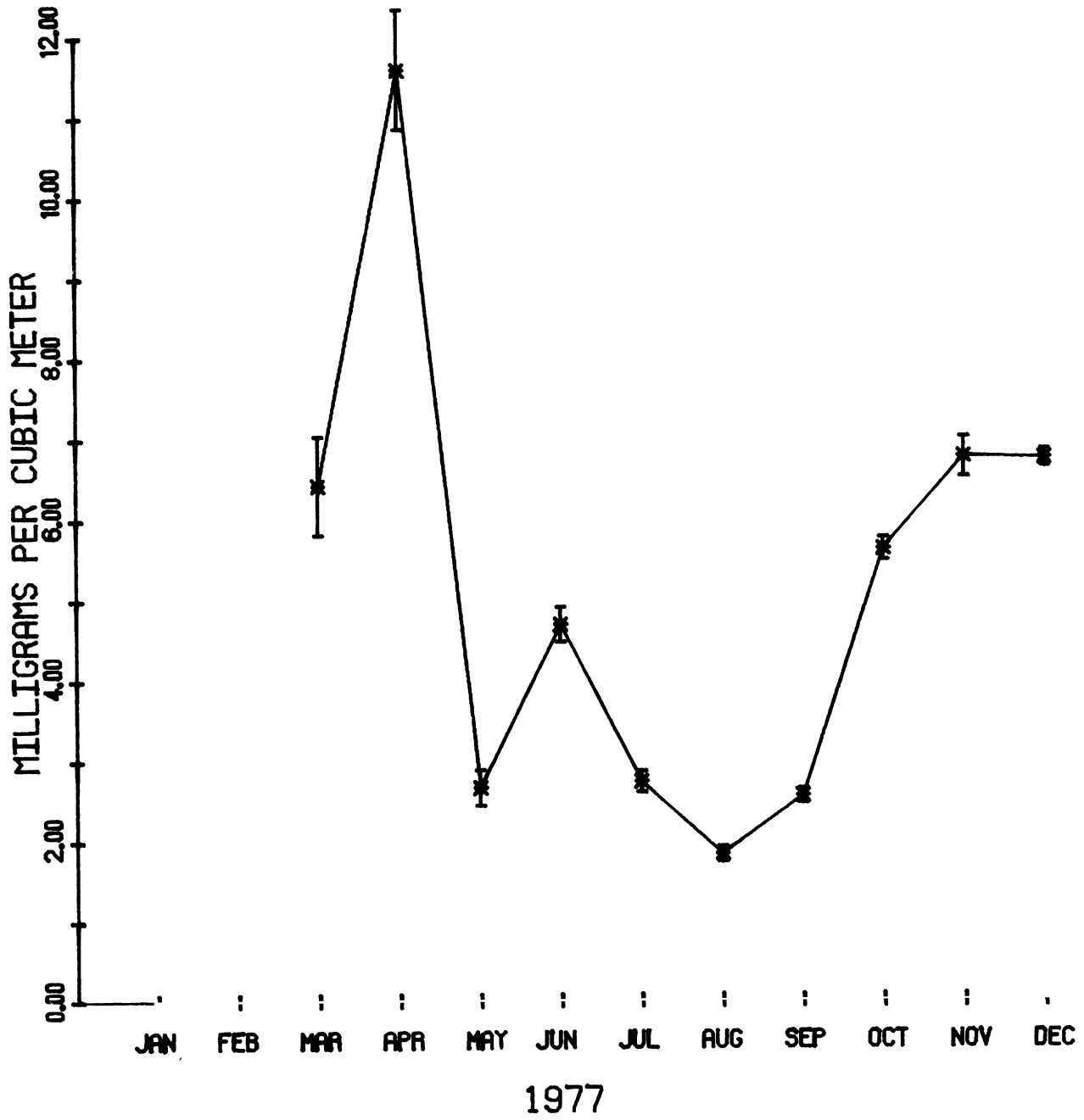


FIG. 73. Variation of chlorophyll a concentrations during 1977.

# CHLOROPHYLL B

MEANS AND STANDARD ERRORS

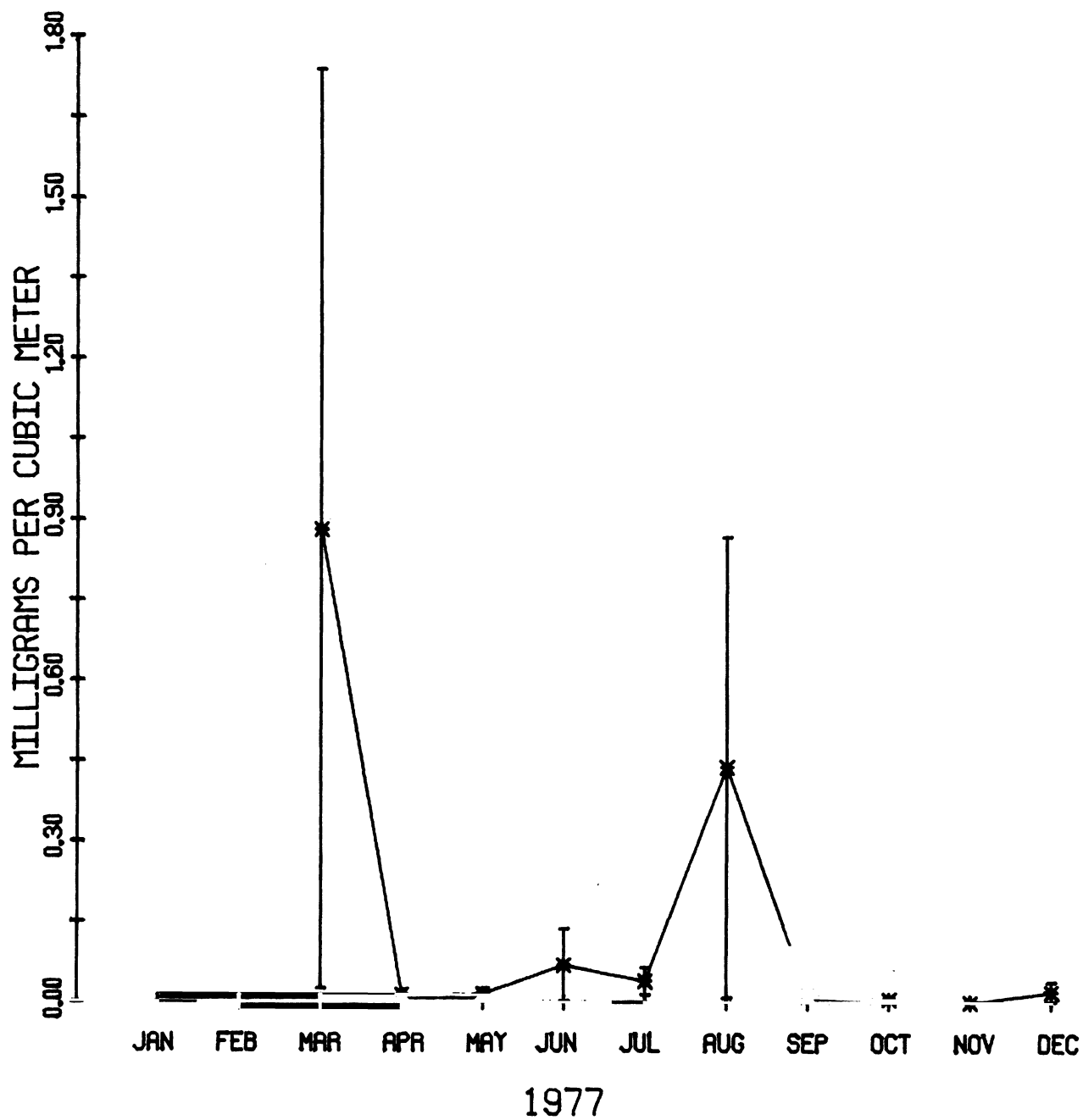


FIG. 74. Variation of chlorophyll b concentrations during 1977.

# CHLOROPHYLL C

MEANS AND STANDARD ERRORS

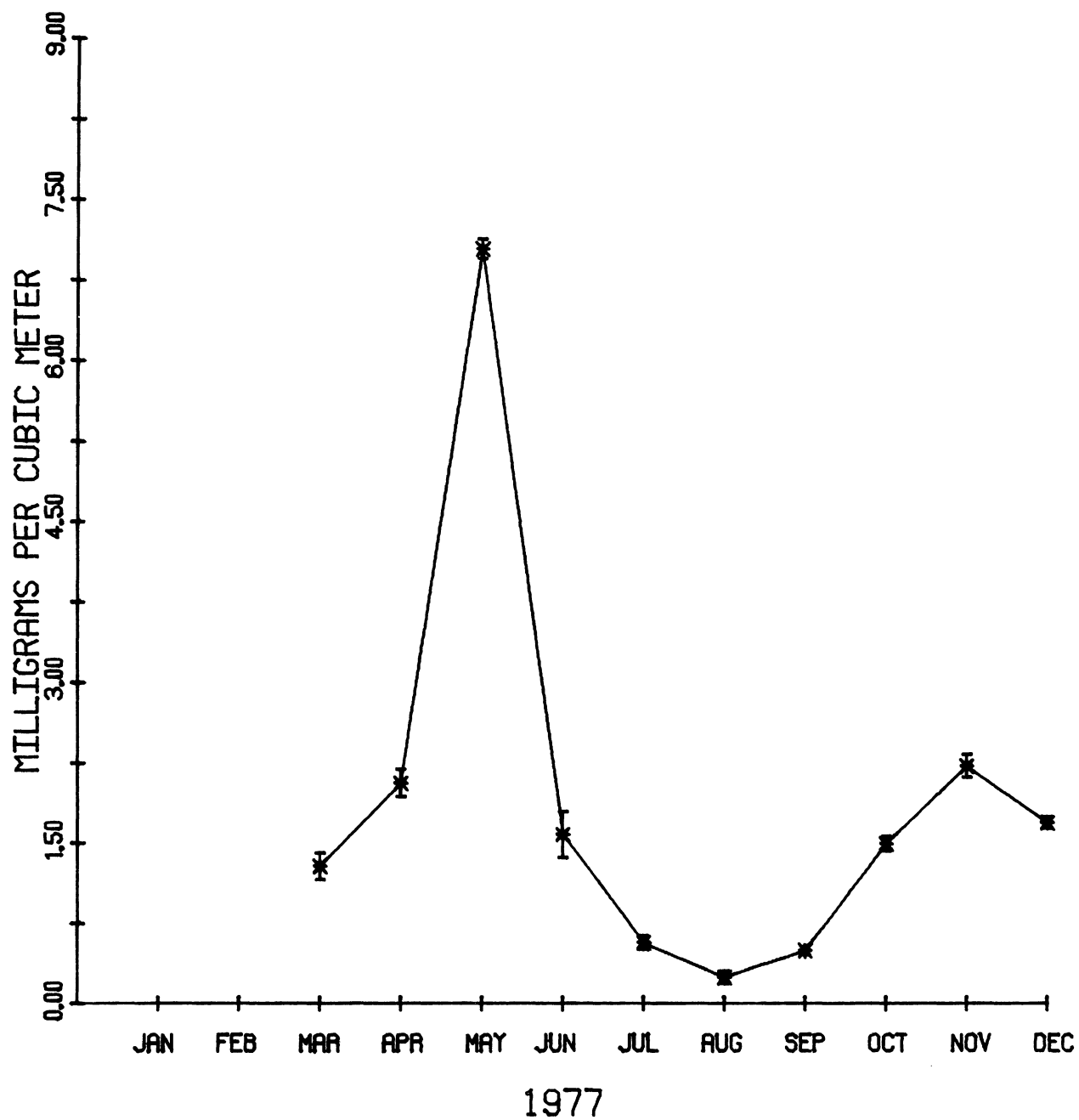


FIG. 75. Variation of chlorophyll c concentrations during 1977.



# PHAEOPHYTIN A

MEANS AND STANDARD ERRORS

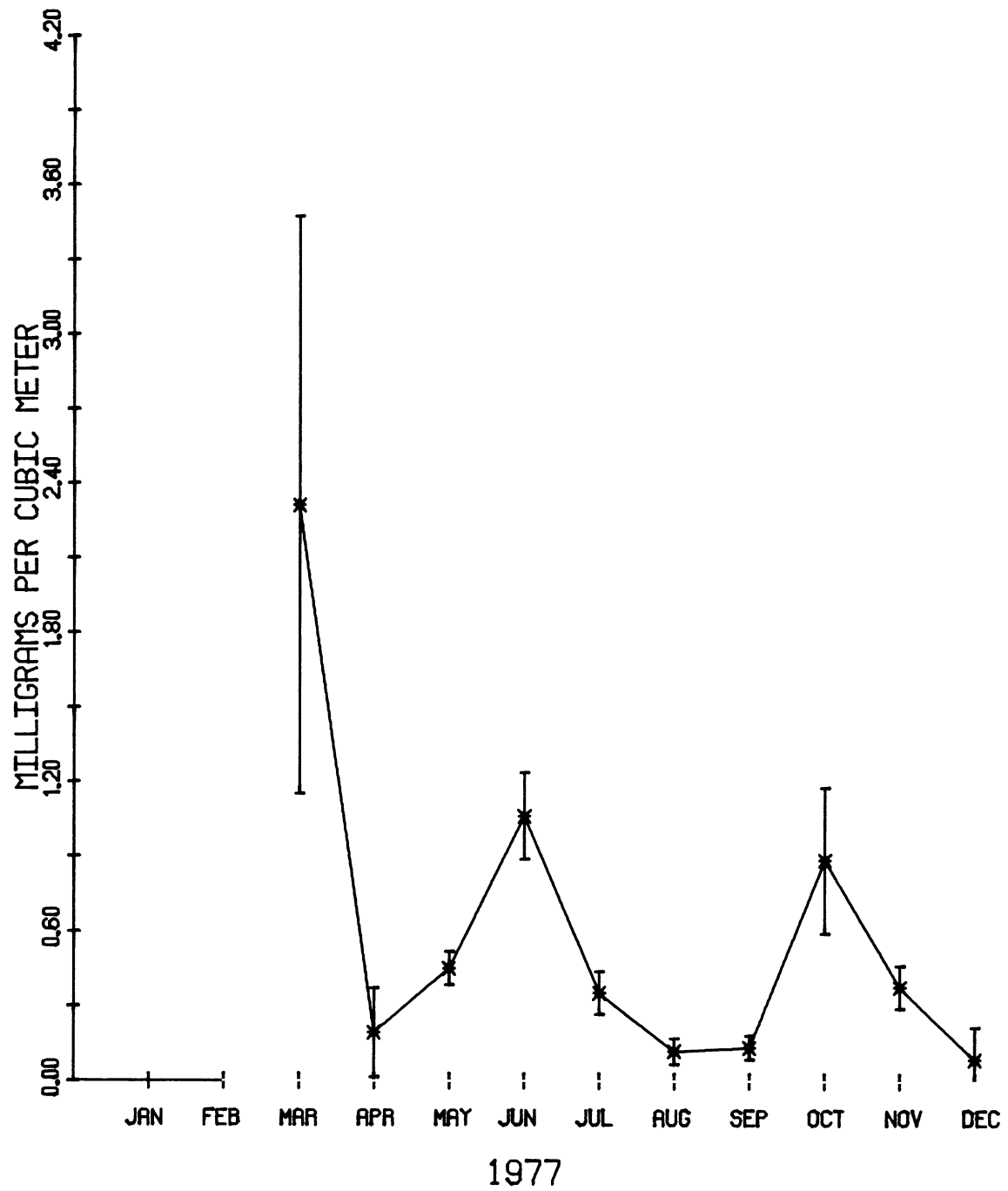


FIG. 76. Variation of phaeophytin a concentrations during 1977.

# PHAEOPHYTIN A/CHLOROPHYLL A

MEANS AND STANDARD ERRORS

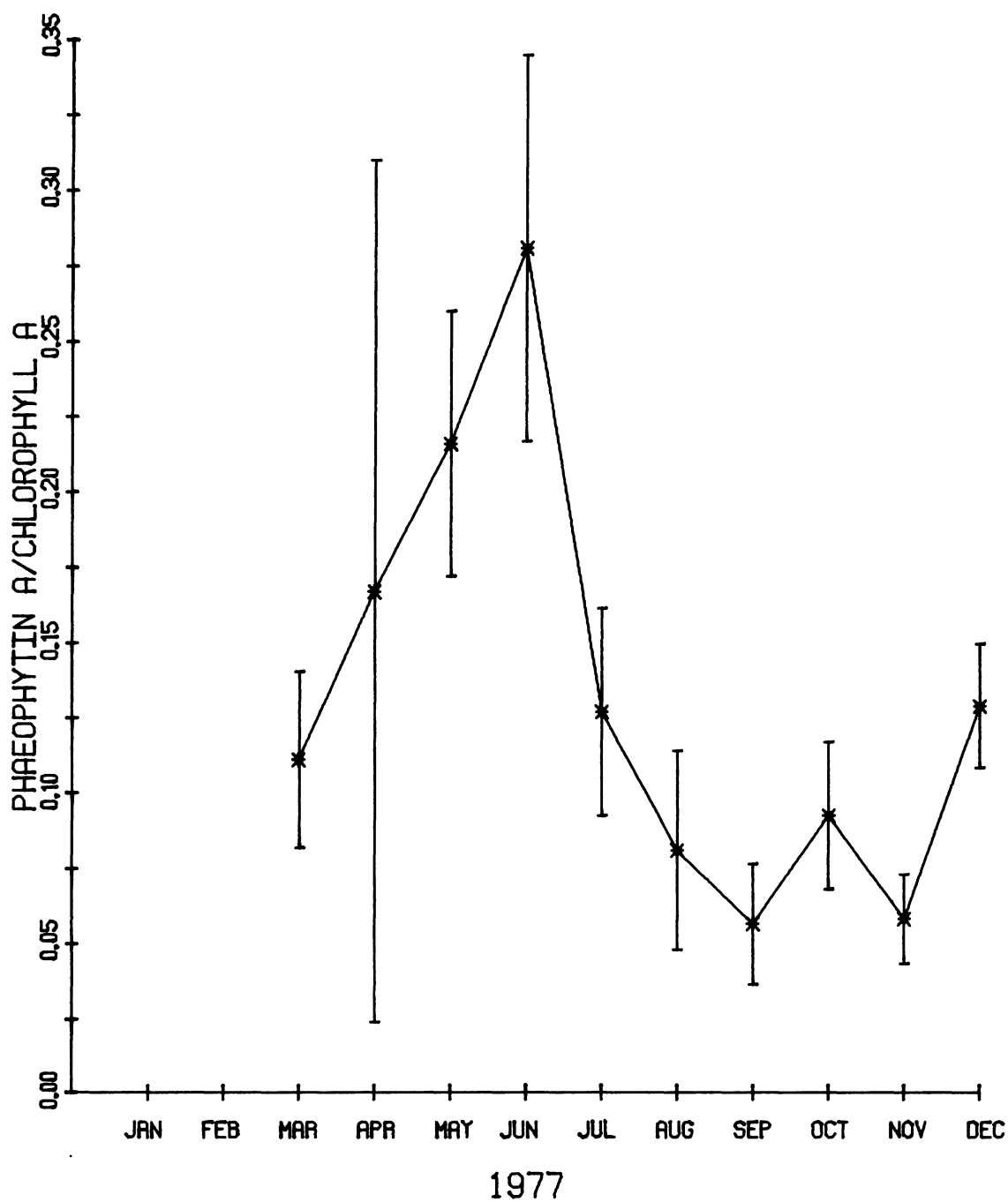


FIG. 77. Variation of the phaeophytin a/chlorophyll a ratio during 1977.

## CONCLUSIONS

During 1977, orthophosphate concentrations ranged between 0.7 and 2.1 ppb. Lowest concentrations were in August, and highest were in September. Nitrate concentrations varied from 0.6 to 2.4 ppm, with lowest in August, September, and December and highest in July. Dissolved silica concentrations were below 0.5 ppm in May through September and December and ranged between 0.1 and 1.1 ppm.

Coccoid blue-green algae were low in concentration during March through July and high in concentration from August through December. Filamentous blue-green algae attained peak numbers in April. During June through August and October, coccoid green algae numbers were relatively high. Filamentous green algae were most abundant during April, July, and November. In March through May and October through November, flagellate concentrations peaked. Centric diatoms were abundant in March through May and July; whereas, pennate diatoms were most abundant in March, April, and October. Desmid numbers were consistently low with a peak in May. Other algae maintained high numbers during April, July, August, October, and November. Total algae numbers were highest in April, July, August, and November.

Comparison of phytoplankton major group mean concentrations for 1975 through 1977 gave the following general observations: 1) coccoid blue-green algae and desmids were least abundant during 1976; 2) flagellates were most abundant during 1976; and 3) filamentous blue-green algae, coccoid green algae, centric diatoms, pennate diatoms, and total algae were least abundant in 1977.

The number of forms of phytoplankton identified during any one month varied from 46 in May to 64 in June. Diversity ranged from 2.98 in May to 4.62 in June, and redundancy varied from 0.223 (June) to 0.474 (May).

The number of forms of phytoplankton was highest in 1976, redundancy was highest in 1977, and diversity was highest in 1976 and lowest in 1977. These changes in community structure statistics mimic changes noted in the major groups, especially for 1977. Decreases in filamentous blue-green algae, coccoid green algae, centric diatoms, pennate diatoms, and total algae in 1977, the increased redundancy in 1977, and the decreased diversity in 1977 describe a phytoplanktonic community considerably different from those of 1975 and 1976.

During 1977, mesotrophic diatom species tolerant of moderate nutrient enrichment continued to increase and those not tolerant of nutrient enrichment decreased. There were increases in numbers of occurrences of flagellates, the blue-green alga Anacystis incerta, chrysophycean flagellates, and Cyclotella comensis. The July peak occurrences of Diatoma tenue v. elongatum, Fragilaria intermedia v. fallax, Stephanodiscus subtilis, and Tabellaria fenestrata v. intermedia were probably related to an upwelling event preceding the week of sampling.

For pre-extraction preparation of chlorophyll samples, grinding continues to be a better technique than sonification. The least detectable difference between intake and discharge chlorophylls and phaeophytin a continues to decrease because of the use of grinding and the increase in replicates from three to five.

During 1977, viability results based on chlorophyll and phaeophytin a data were considerably different from those of previous years. Decreases in viability occurred in 16% of the samples compared to 3.6% in 1975 and 5% in 1976. Viability increased in less than 1% of the samples. It increased in less than 1.8% and 3.8% of the samples collected in 1975 and 1976, respectively. This impact is believed to be related to the change in the phytoplankton community during 1977 which was in some way more susceptible to

apparent plant impact. However, the increase in the number of times in which changes in phytoplankton viability were detected is in part due to methodology changes which allowed greater numbers of statistically significant changes to be detected during 1977. Further data will be required to assess if the changes noted were caused by plant impact or simply a result of methodology changes.

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